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TECHNICAL REPORT NO. AFWL-TR-73-103

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AIR FORCE WEAPONS LABORATORY

Air Force Systems Command

Kirtland Air Force Base

New Mexico

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FOREWORD

This report was prepared by Battelle Laboratories, Columbus, Ohio, under Contract F29601-73-C-0008. The research was performed under Program Element 61101F, Project ILIR-7220.

Inclusive dates of research were 24 August 1972 through 1 April 1973. The report was submitted 16 April 1973 by the Air Force Weapons Laboratory Project Officer, Captain George B. Carroll, Jr. (DEE).

In addition to the authors listed on the cover, Mr. William Baytos, Mr. Nick Conkle, and Mr. Dan Chase prepared parts of this report.

This report has been reviewed and is approved.

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ABSTRACT

The Air Force requirements for a mobile field laboratory were determined by visits to McClellan and Kelly Environmental Health Laboratories and by observations of a Kelly field team surveying the wastewater problems at McGuire Air Force Base. The major requirements of mobile laboratories are:

(1) They should be a container for unified damage-free shipment of the laboratory equipment.

(2) They should provide working space for the field team and a place to use analytical equipment.

(3) They should reduce the set-up, tear-down, packing, and unpacking time and manpower requirements.

(4) They should be transportable on the public highway and by C-130 aircraft.

(5) They should provide for laboratory utilities.

The technology for mobile laboratories was determined by visits to the EPA and U. S. Army mobile laboratories and by telephone contact with many other mobile laboratory operators. Existing laboratories would not meet all of the Air Force requirements, primarily because none fitted into a C-130 aircraft and partly because each laboratory was designed for the specific missions which were different from Air Force missions.

After evaluating several alternate designs, mobile laboratories for air- and water-quality analyses were designed into a modified, semi-trailer. Other field analytical groups in the Air Force could use mobile laboratories based on these designs.

The utility functions--heating, cooling, hot and cold water supplies, electricity, and compressed air--were designed permanently into the semi-trailer. The analytical functions were designed into modules which could be placed in, and removed from, the laboratory as required by the specific mission.

The overall cost of a mobile laboratory without analytical modules was estimated at $34,560 and the cabinetry associated with the analytical modules at up to $11,080, depending upon the specific modules chosen.

(Distribution Limitation Statement B)

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SECTION I

INTRODUCTION

The U.S. Air Force has been charged with a primary national defense mission. In order to accomplish this mission, the Air Force operates bases and facilities in specific local and regional environments. Each of these bases and facilities has a specific impact on its environment. The Federal Government has been acutely aware of this collective impact and has issued directives toward the minimization of negative environmental effects. The Air Force has responded by the publication and dissemination of AFR 19-1,2 which contained specific directives to Air Force base commanders.

With manpower limitation stressed by the Federal Government, each base cannot afford to staff and maintain its own emissions monitoring facility. With the Federal Government's continued emphasis on environmental pollution abatement, every effort must be made by base commanders to assure maximum pollution control or industrial hygiene field survey effectiveness by minimizing temporary duty, special assignments, and excessive, unexpected commitment of key Air Force personnel.

The characteristics of the pollution problem currently facing the Air Force are very similar to those facing large municipalities in America today, because a large Air Force base is a microcosm of urban American life. It is typically characterized by a heavy volume of traffic, both from aircraft and terrestrial vehicles, and a wide variety of industrial operations. In addition, it contains a large military airfield and special mission-oriented and base functions such as engine testing, aircraft operation and maintenance, motor vehicle maintenance, in some instances liquid oxygen plants, missile operation and maintenance, and other functions.

This diversity of operation gives rise to air, water, solid waste, thermal, and noise pollution problems typical of those found in large urban centers. In essence, the pollution problems facing the

Air Force base commander are the same as those facing the administrator of a large municipality. Such problems as reducing engine exhaust (NO_x, CO, unburned hydrocarbons, etc.), reducing industrial air and water emissions, recycling solid waste, designing an adequate landfill to prevent leaching of pollutants to the groundwater, reducing the ambient noise level, and ensuring adequate sewage treatment facilities to prevent discharge of untreated sewage are but a few of the environmental impacts that must be considered and solved.

From a strictly technical point of view, solution of the Air Force pollution problem should be much easier than the solution of a similar situation for a municipality. Access to mass and energy balance information upon which emissions are determined should be much easier to obtain for operations at Air Force bases.

Although the types of pollution problems faced by the Air Force and municipality are similar, there is one very important difference. In trying to solve the pollution problems of municipal life, the city administrator must gain the support of many special interest groups before effective, innovative programs can be undertaken. Quite often the options available to the city administrator are limited to decisions dictated by political compromise. Outside of economic considerations, such restrictions should not hinder the Air Force. Each base is in essence a separate community subject to the wisdom and responsibility of the base commander. Consequently, if ever there existed an opportunity for effective municipal planning of innovative pollution abatement programs, here is that opportunity. In essence, the integrated pollution control programs instigated by the Air Force could serve as a prototype or pilot model for innovative municipal pollution control programs throughout the country. The public relations and service values of an effective Air Force program would indeed be immense.

Efficient pollution abatement control programs require a measure of the magnitude of the problem and identification of the source of the contamination. Measurement and identification require facilities

for analysis, measurement, and surveillance. These functions are best accomplished by mobile field laboratories.

The USAF Environmental Health Laboratories exemplify organizations which require the use of such a mobile laboratory. They are customer-oriented organizations designed to expand economically the capabilities of the USAF base-level environmental health and pollution abatement programs with services that are not reasonable to possess at each base. To accomplish their assigned Air Force responsibility, the Environmental Health Laboratories conduct numerous and increasingly complex field environmental surveys at Air Force bases around the globe. The types of surveys performed include the following:

- Industrial hygiene surveys
- Water and air pollution surveys
- Veterinary-toxicology studies
- Industrial x-ray surveys
- Noise studies
- Medical-dental x-ray surveys.

At the present time, these surveys may require more than four tons of equipment and supplies to be moved to a remote site, along with as many as ten engineers, scientists, and technicians. Even then, mission effectiveness suffers from lack of adequate laboratory work space convenient to the survey site. Many of the problems encountered in these complex surveys could be overcome by the use of an appropriately outfitted, transportable field laboratory which would enable field analysis of samples that either require elaborate instrumentation, would deteriorate in shipment to a central laboratory, or require immediate analysis to enable on-site changes of operating parameters to produce optimum survey effectiveness.

In addition to routine field surveys, the Environmental Health Laboratory and other environmental monitoring response teams require a mobile laboratory which can be easily transported to a site where an operational or accident situation is causing an adverse environmental

impact on the local community. Only by having environmental samples quickly and accurately analyzed can the extent of the environmental damage be assessed and the corrective measures and their effectiveness be evaluated. This need for a complete and mobile laboratory, which can be moved over land and through the air, must be met through an R&D effort.

While a capability for performing some types of field survey operations already exists, the Air Force needs to strengthen and broaden this capability because of the increasing complexity of the mission requirements. This augmented capability will include the use of modern, self-sufficient, land-mobile and air-transportable environmental laboratories capable of emissions sampling, monitoring, and field analyses in response to specific missions.

The overall objective of this program was to provide the Air Force with the basis for an augmented field survey capability of broad effectiveness. The specific objective of this program was to establish and recommend the configurations to be adopted for each of two modular mobile laboratory designs.

The general approach to this program included the following key elements:

- <u>Interviews</u> of Air Force personnel to establish in detail current procedures, as well as probable future needs
- <u>Acquisition</u> of current information on the design, construction, mission, effectiveness, and cost of mobile field survey laboratories
- <u>Participation</u> in Air Force field surveys
- <u>Analysis</u> of the pertinent and available methods, needs, procedures, and technology employed in pollution monitoring
- <u>Development</u> of specific modular designs for two mobile field survey laboratories primarily in the air and water areas
- <u>Recommendation</u> of these designs for detailed review by Air Force personnel.

SECTION II

DEVELOPMENT OF MOBILE LABORATORY REQUIREMENTS

The Air Force Environmental Health Laboratories (EHL) at Kelly and McClellan Air Force Bases were visited to determine their requirements for facilities in a mobile laboratory and to obtain insight into the type of laboratory that would serve their purposes. Over a period of time, the personnel at these bases have built, purchased, or modified equipment so that, when visited, equipment was available for most of their requirements both in the field and at the base. Most of the equipment taken into the field has withstood the test of many field trips. A major concern at both bases was the shipment of the equipment, losses and damage in shipment, and the packing, unpacking, setup, and teardown time and manpower associated with a field laboratory. The chemists and engineers at the Environmental Health Laboratories were familiar with analytical equipment available for mobile laboratories and knew the equipment requirements both for present and future missions. The requirements for a mobile laboratory as expressed at the Environmental Health Laboratories was, in order of importance:

(1) To provide a shipping container which would be easy to pack and unpack and could be shipped in one package

(2) To provide workspace for some field personnel

(3) To provide a place to store and use the field equipment while at Kelly or McClellan base.

It was envisioned that in actual use the mobile laboratory would not only contain supplies and equipment in the storage places provided, but additional equipment and supplies would be transported in the aisles and on bench tops and then used on site outside of the mobile laboratory. Packing techniques would be needed for both equipment mounted in modules and equipment shipped in the storage and aisle spaces. Some equipment would be partially disassembled for shipment. The fixed

cabinetry and modules in the laboratories could be removed or modified for insertion of new modules to meet new, special, or emergency missions assigned to the Air Force.

REQUIREMENTS OF ENVIRONMENTAL HEALTH LABORATORY KELLY AFB, TEXAS

The water pollution mission of the Environmental Health Laboratory at Kelly Air Force Base was primarily concerned with monitoring the effluents from sewage treatment plants and runoff water from air bases. A chemical and biological laboratory was required to support the field team which visited other air bases to survey effluent waters.

The Kelly EHL performed field analyses for total oxygen demand, chemical oxygen demand, five-day biological oxygen demand, five-day biological oxygen demand from soluble material, total solids, total dissolved solids, total volatile solids, suspended solids, methylene blue active substances, phenols, alkalinity, cyanide ion, hydrogen ion concentration, turbidity, color, chloride ion concentration, hypochlorite ion concentration, coliforms, fecal coliforms heavy metals, total hardness, oil and grease, nitrogen forms, and phosphorus in accordance with Standard Methods. (Ref. 1) In addition, the field team measured stream flow, performed bioassay work, and performed sewage treatment pilot plant work. Hydrocarbon and total organic carbon analyses were to be added to the field capability. The maximum size of the field team from the water quality laboratory was 17 men, although most missions required fewer personnel. In addition to the water analyses, the EHL group at Kelly performed noise analyses and expected to receive assignments in the occupational safety and health area. The noise survey function probably would not require a mobile laboratory as only a tape recorder, a noise meter, and other portable equipment were used. The recorded sounds were analyzed at the base. In the occupational safety and health area, capabilities were required for collection and analyses of respirable dusts,

solvents, pesticides, and other harmful materials. This work would require a rather complete chemical laboratory, comparable in size to the water analysis laboratory.

The base laboratory at Kelly provided administrative support for the field operations; a base for calibration, repair and realignment of field equipment; and analyses using nontransportable analytical instruments which included sophisticated mass and optical spectrometers, atomic absorption instruments, infrared analyzers, gas chromatographs, Technicon autoanalyzers, a total organic carbon analyzer, a real time noise analyzer, and an algebraic programable calculator. In their most sensitive design, these instruments required accurate alignment which could not be maintained in the field. Some of these instruments were available for field use in less sensitive and more rugged designs.

As an aid in the determination of the requirements for an Air Force mobile laboratory, the field team from Kelly AFB was visited at McGuire AFB during a survey of stream pollution. The field team consisted of seven officers and ten enlisted men and represents a maximum capability of a Kelly field team. Chemical analyses of water, bioassay of water, jar tests for sewage treatment, and stream flow measurements were made on this survey.

Chemical Analyses

The chemical analyses of water were performed in a building about 50 ft x 20 ft x 6.5 ft high. The building was crowded. The chemical analyses included total oxygen demand, chemical oxygen demand, five-day biochemical oxygen demand, five-day biochemical oxygen demand of soluble material, total solids, total dissolved solids, suspended solids, total volatile solids, methylene blue active substances, phenols, alkalinity, cyanide ion, hydrogen ion, turbidity, color, chloride, hypochlorite, coliforms, heavy metals, and hardness. Analyses performed by the Army, which was cooperating in the survey and for which the Air Force has field

capability, were total organic carbon, oil and grease, nitrogen forms, and phosphorus. An ultimate oxygen demand (which is a 20-day BOD) analysis would be performed on samples returned to Kelly AFB and would not be a field analysis. Spectroscopic analyses were also performed on samples returned to Kelly. The analytical equipment used on this field trip and others is described in the later section on specific instrument considerations for the mobile laboratories.

Bioassays

The bioassay group was set up in a compressor room and in the sewage plant at neighboring Fort Dix. This group required a separate building from the chemical laboratory because chemical fumes would interfere with bioassays. Bioassay required about 30 sq ft of bench area. The equipment was shipped in 9 boxes, 2 ft high x 3 ft wide x 4 ft long. The sampling kits were battery powered and electrical outlets were needed for recharging. Equipment included microscopes, dredges, stream flow meters, diluation board for fish bioassay, seines, static fish cages, and DO and temperature recorders. Much of the equipment was used outside of the laboratory.

Stock cultures of test organisms, the fat head minnow (Pimaphales promelas) and water fleas (Daphnia) were maintained at the base laboratory in an area away from the chemistry section. The purpose of maintaining the cultures was to provide a standard test organism for continuous flow bioassay experiments. The continuous flow bioassay technique was a test that simulated field situations. In other stream studies the Kelly EHL biologists identified and enumerated the aquatic biota found in streams near the sewage treatment plant. Static fish cages, stocked with native fish were planted at critical locations in the stream. The results from these tests indicated the type and degree of pollution.

Sewage Treatment

Jar tests were made to investigate sewage treatment parameters. Two large multiple stirrers occupied about 6 linear ft of bench space each. The stirrers required an electrical supply. Samplers were battery operated and required an electrical supply for battery charging. This equipment was set up in the sewage treatment plant building. On other trips, the determination of parameters for tertiary treatment of sewage may be made. The equipment consisted of charcoal-packed, clear plastic columns 6 in. diameter by 12 ft high, with joints at 6 ft. This test was conducted outdoors. Space for shipping five of these columns was needed.

The Mettler balances for the chemistry laboratory were in the sewage treatment area because the traffic and light floor in the chemistry building made use there impossible. The Mettler balances required an electrical outlet.

In addition to the laboratory equipment, 2 or 3 desks and some office space were needed. Space should be provided for an electronic calculator such as one in use, a Hewlett-Packard Algebraic Programable Calculator, Series 9000, Model 10A. This calculator required a standard electrical outlet.

REQUIREMENTS OF THE ENVIRONMENTAL HEALTH LABORATORY McCLELLAN AFB, CALIFORNIA

The major effort of this team was to measure ambient air quality and monitor stack emissions from stationary combustion sources, primarily base operated power plants and steam generators. The ambient air measurements included ozone, hydrocarbons, nitrogen oxides, sulfur dioxide, hydrogen sulfide, and particulates. Stack emissions measurements include carbon monoxide, carbon dioxide, nitrogen oxides, sulfur dioxide, hydrocarbons, and particulates. One or two points were sampled at a time and

the sampling crews consisted of 2 to 6 men. Field trips ranged from 2 days to 6 weeks. Analytical capabilities required were limited to analytical procedures published in the Federal Register (Ref. 2) as directed by the EPA. Occasionally, noise and industrial hygiene surveys were performed, and these capabilities essentially duplicate those of Kelly's EHL.

For ambient air monitoring, five-ganged high-volume samplers were used in conjunction with a meteorological station. The meteorological station measured and recorded automatically the temperature and air velocity at 6- and 50-ft elevations. An anemometer was mounted on a portable, 50 ft high telescoping tower. Particulates were determined in the field, but if metals' identification was needed, the samples were returned to the central laboratory at McClellan. A spinning disc aerosol generator was used for instrument calibration, while in the field.

Stack sampling was performed using standard EPA procedures. For particulates measurement, a self-contained, all-glass sampler, based on the Public Health Service's source sampling train, was used. The sampler was fitted with either 4- or 8-ft probes, Greenburg-Smith impingers, a dry gas meter, and an inclined manometer. Nitrogen oxides were measured by the Saltzman and Jacob-Hochheiser method. Carbon monoxide and carbon dioxide were measured on the MSA infrared instrument. All of the instruments were maintained and calibrated at the home base laboratory.

In addition to the two Environmental Health Laboratories, Air Force groups were interested in monitoring and measuring radiation and effluents and exhausts from aircraft. In environmental emergencies, such as petroleum spillage, the mobile laboratories could be used to help determine a course of remedial action.

SURVEY OF EXISTING MOBILE LABORATORIES

A survey of existing mobile monitoring facilities has been conducted to determine if there are existing mobile laboratories which could be adapted to meet Air Force needs. This survey was designed to cover selected sources most likely to be engaged in activities similar to those of interest in this program. These sources included the open literature, the report literature, the Federal Environmental Protection Agency, the U.S. Army, the U.S. Navy, state agencies, and private companies.

EPA Mobile Laboratories

The EPA group at the National Field Investigations Center in Cincinnati has been making field investigations for over 25 years. They had four mobile laboratories, two for chemical analyses, one for bacterial analysis, and one for bioassay. One of the chemical analysis vans was built in 1963, the other in 1967. The bacteriology van was built in 1967 and the bioassay unit was built in 1971. All were designed by Carl Hirth of that agency. The mobile laboratories basically take the form of a box, 20 or 22 ft long, 8 ft wide, and 8 ft high which was mounted on a truck chasis.

Internally, a 2-ft-wide-laboratory type bench with Formica top was permanently installed along the walls. Standard laboratory cabinets were mounted underneath the bench. Each drawer or cabinet was equipped with a lock because the catches provided with the cabinets allowed the drawers to come open in transit. The floor of the van was used for storage in transit. Sometimes a truck was rented at the investigation site to be used as a warehouse for excess equipment.

A 21,000-Btu/hour air conditioner was installed and 8 Kw of electric heating was available. The wall, ceiling, and floor of the laboratory were insulated. A laboratory hood mounted in one of the

vans used outside air for ventilation rather than pulling laboratory air out through the hood, thus decreasing heating and cooling requirements. Additional ventilation fans were mounted in the walls for extra ventilation when needed. The windows in the walls could cause a minor problem because of sunshine blinding the workers in the lab. However, they were recommended because workmens' morales were improved with windows and the sunshine was only an occasional problem. The fluorescent lights were equipped with special locks to prevent the bulbs from falling out in transit. The water and electric lines were mounted on the walls above the laboratory bench. This was found to be more satisfactory than mounting in or under the cabinets, primarily because a narrower cabinet can then be utilized since space is not required in the cabinet for these lines; also, the wall mounted lines are more accessible for drainage and repair. The water lines should be designed for easy drainage to prevent freezing during transport.

The Air Force Mobile Laboratories could not be based on the EPA laboratories' design because the EPA facilities were about 11-1/2 ft high (an 8-ft laboratory on a 3-1/2-ft high chassis) and thus were not transportable in a C-130. The EPA preferred self-propelled units because they believe transportation costs were reduced and they retained control of the van during shipment.

U.S. Army Mobile Laboratories

The U.S. Army Environmental Hygiene Agency, Edgewood Arsenal, had two semi-trailers, both almost identical outside but equipped differently inside. The major purpose of the mobile laboratories was for sampling and analyzing industrial wastewaters. One unit, the chemistry laboratory, was used primarily for performing wet chemical analyses. The other, the Technicon Unit, contained 4-automated analyzers. In addition, the trailers were used for transporting field equipment for use outside of the trailer laboratories. This extra equipment was set up in a building at the test site.

The mobile laboratories were built using a standard 36-ft long by 8-ft wide trailer shell with a single rear axle. The floor was about 4 ft, 6 in. above ground and the overall height was 12 ft, 8 in. Access was through double cargo-type doors at the back and a 3-ft wide door at the center of one side. At a test site, the trailers were jacked up to obtain a stable floor. A commercial hauler was hired to move the laboratory.

The chief chemist for the laboratory suggested consideration of the following changes for a new unit. Tandem axles and air suspension would permit the trailer to take a heavier load and give a softer ride. A safer stair arrangement was needed because a person opening the door from the outside could upset and fall off the steps. Another exit door which cannot lock a person inside was needed because of the possibility of being trapped by fire. (A wall partition across the width of the van, 9 ft forward of the rear door, separated the trailer into two rooms, with no door between.) The lack of windows did not bother the personnel. The unit had tie-downs on the floor, and additional tie-downs for equipment should also be placed on the walls. The cabinet work had protruding handles while recessed handles would have been preferred because equipment loaded in the aisles for transport damaged the protruding handles. Loose equipment was shipped in footlockers and the footlockers also should have recessed locks and handles. The units received rough treatment in transport and a weaker unit such as those used for mobile offices probably would not be satisfactory.

A 100-amp, 120-ground-120-volt electric circuit was used for each trailer and modifications for 150-amp service were under consideration. The cable connectors for the extension cord were not generally available and the electric wires supplying power to the mobile laboratory usually went to a box furnished by the mobile laboratory. A double spigot on the water inlet was recommended so that water is available outside and also for hookup to a second trailer. A small firehose was used for the sewer connection.

The rear 9 ft of the chemistry van comprised a small room which contained a total organic carbon (TOC) analyzer, pH meter, turbidity meter, and an ion-analyzer for ammonia. It also contained a 10-gal storage tank for distilled water, an air compressor, and a small sink (airline type) perhaps 4 in. deep by 6 in. wide by 8 in. long. The front of the room was covered with shelves. The total organic carbon analyzer was sensitive to shock and the manufacturer's serviceman recalibrated it after each transport. The shelves should be designed so equipment would not fall off during shipment.

In the wet chemistry lab, the counter tops and sinks were stainless steel which was recommended for a wet chemical laboratory. The Barnsted Model 210 still (2 gal/hr, 10 gal storage) was regarded as inadequate because of limited storage. Hot distilled water, fresh from the still, was normally used while cooled water would have been preferred. Two sinks, 30 in. long by 15 in. wide by 12 in. deep were in the laboratory and were satisfactory. Small cups were used to drain cooling water from distillation condensers. A standard 4-ft hood was mounted in the laboratory.

An undercounter type of refrigerator was recommended. The shelves in the laboratory were mounted on brackets on the wall and the height of the shelves could be adjusted as desired. The Mettler balance was shipped in a box with the knife removed. No vibration problems were noted when weighing. The ovens for determining solids should be in one place because they heat that area of the laboratory. The vacuum source for filtration should be a vacuum pump. Some of the drying ovens were permanently mounted in the van. Some glassware was taped to pegboards for shipment and this method of shipment does not cause breakage. Pipettes and other glassware were placed in cabinets with drawer dividers for shipment. A fire extinguisher and fire blanket were in the laboratory.

The rear of the Technicon van contained a small room similar to the chemistry van. The room contained a sink, bench, and air compressor and the front wall was covered with shelves. The room was used to receive the bulk samples and to break them down for each of the analyses needed.

The Technicon equipment for automatic analyses of nitrite, nitrate, phosphates, phenols, and ammonia was mounted on one side of the main laboratory in the Technicon trailer. The supplies for the equipment were in the cabinets on the other side. The bench for the Technicon equipment had a plastic top. The walls of both units were Formica.

The additional equipment setup in space provided by the Twin Cities Arsenal included 4 refrigerator-size BOD boxes, of about 500-bottle capacity each, and all of the sampling equipment. Sample carriers and samples (to be returned to Edgewood for further analysis) along with empty footlockers for the equipment were also stored in a building. At most installations much of this equipment was stored under the trailers.

U.S. Army Medical Environmental Engineering
Research Unit, Edgewood, Maryland

This group was developing specifications for a mobile laboratory trailer to be used by USAEHA. The trailer was to be designed to do bioassay work, biological oxygen demand determinations, treatability studies and coliform determinations. They anticipated utilizing a 35-40 ft semi-trailer for this laboratory.

U.S. Navy Facilities

Naval Civil Engineering Laboratory,
Port Hueneme, California

The Environmental Protection Data Base group operated mobile units for both air and water pollution monitoring. These were custom built units similar in concept to other designs being reviewed.

Naval Ships Research and Development
Center, Annapolis, Maryland

The Environmental Laboratory has a mobile unit for water monitoring which was built into a house trailer. They have designed a larger laboratory to be housed in a semi-trailer which will soon be put out for construction. This unit will be equipped for water analysis.

State Agencies

The Air Pollution Office of the Department of Industrial Health of the State of Michigan operated a number of monitoring laboratories. These were built in house-trailer type vehicles ranging from 15 to 30 feet in length. While they were mobile, they were normally operated for long periods of time at fixed locations.

The Department of Surveillance of the newly created Ohio Environmental Protection Agency was in the process of obtaining monitoring and analysis equipment for water quality measurement. They will use a strong central analytical laboratory supported by a mobile unit in each of the four districts. The mobile units will serve primarily in a sample collection mode and will have only limited monitoring capability.

Other Sources

The Environment Engineering group at the Construction Engineering Research Laboratory, Champaign, Illinois, has designed a "research laboratory on wheels" for studies of air, water, noise, and solid waste pollution. They have developed a modular approach to accommodate all of the required areas of research. They have recently completed a request for proposal for the construction of the facility.

Both General Motors (Refs. 3, 4) and Ford (Ref. 5) had mobile laboratories designed for testing automobile emissions. These were semi-trailer-type vehicles fitted with instrumentation specific for automotive emissions testing.

A listing of companies supplying products or services under the heading of portable laboratories, appeared in Environmental Science and Technology (Ref. 6). Subheadings included air sampling, sewage sampling, water sampling, and other.

Two commercial advertisements describing mobile laboratories for pollution monitoring were included in the references found. (Refs. 7, 8) Literature has been requested from both firms and received from Calumet Coach. Calumet Coach, a commercial builder of a variety of different mobile units, produces a mobile instrument van and a trailer laboratory. The units come with complete basic laboratory furniture, heating, and cooling units, water systems and storage, etc. Because of height and length limitation, the units advertised are not air transportable. Specially fabricated units to meet the desired requirement could be ordered and Calumet Coach should be considered for fabrication of the desired unit.

The final references described existing mobile laboratories being used for the type of monitoring carried out by the Air Force Environmental Health Labs. General Motors had a 31-ft mobile laboratory which was moved from one major city to another to measure ambient air quality. Various air pollutants as well as meteorological phenomena were monitored. A mobile air conservation van has been described (Ref. 10) with capability for continuous monitoring of ozone, hydrogen sulfide, carbon monoxide, total hydrocarbons, particulate matter, sulfur dioxide and the oxides of nitrogen as well as a number of meteorological parameters. A digital data acquisition system was used for collection of this data, at selected real time intervals, for computer processing at a later time. The Los Angeles Department of Water and Power employed a $100,000 air-quality mobile laboratory to monitor emissions from its four power plants (Ref. 11). The Gulf Oil Company utilized mobile monitoring vans to survey pollutant levels at its refineries and plants (Ref. 12). Separate mobile units were employed for air and water quality measurements.

Summary of Mobile Laboratory Survey

The review of existing facilities revealed that there are few mobile laboratories designed to accomplish the complete environmental pollution monitoring task which is required of the Air Force Environmental Health Laboratories. However, the survey was very valuable in identifying desirable design features and in obtaining suggestions from users of mobile laboratories.

SECTION III

DESIGN OF MOBILE LABORATORIES

The mobile laboratories will be used by the Air Force for a wide range of missions and each mission may be unique and different. If all possible functions were to be placed in a laboratory, it would be impractically large and expensive. Because of the wide range of missions, both now accomplished, and probable in the future, analytical instruments and related equipment for specific analyses should not be permanently built into a laboratory. However, space is needed for specific analytical equipment. Because some general facilities are needed on all missions, this equipment should be built into a mobile laboratory. Since men may work in the laboratory for 12 or more hours per day, a comfortable working area is needed. Therefore, the laboratory should be heated and air-conditioned. Much bench space is needed. Sources of abundant electric power and electric outlets, storage space, hot and cold water, pure water, and drains are needed on almost all missions and should be permanently built into the laboratory. The general concept of a laboratory which will meet these needs is one with built-in utility functions and replaceable modules for specific analyses. In most existing mobile laboratories, equipment is transported in the laboratory and installed at the test site outside of the laboratory. Therefore, the laboratory needs provision for transporting such equipment in the working space within the laboratory.

The design of the laboratory was considered in several parts. First the container or shell for the laboratory was specified. The size was determined by the amount of equipment and working space needed and by the constraints of making the unit land mobile and air transportable. Second, the utilities were specified and designed into the laboratory. This specification required an estimate of the maximum mission of the laboratory. Third, equipment was specified for the laboratory, and provision was made for placement of equipment in the laboratory. Since

the equipment will vary from mission to mission, and also may be used outside of the laboratory at the field site, provisions were made for easy placement in and removal from the laboratory.

The analytical techniques used in pollution control are subject to change. The changes reflect improvement in instrumentation, a better understanding of the relationship of analytical measurements to the detrimental effects of pollution, and an increasing awareness that a wide variety of measurements are required to identify and correct pollution problems. For these reasons the mobile laboratory was not designed for a specific analytical instrumentation system, but included provision for installation of improved or new analytical systems. However, parts of the laboratory supply needs which should be constant in the future. The instruments need electric power, human operation and maintenance, water or air cooling, washing of some of the components samples, and an exhaust. Therefore, utilities for these functions were designed into the laboratory.

SHELL FOR MOBILE LABORATORIES

The shell for the mobile laboratory must be durable because it will be subject to stress in transportation. It must be insulated for weather protection, and be large enough to house the laboratory, and small enough to fit in a C-130 and to be moved by highway.

The durability feature was a matter of judgment. Generally, equipment which gave good service in rough daily commercial service was considered durable.

To be land transportable, a vehicle should be less than 45 ft long and 8 ft wide because of legal restructions on highway usage. Larger units can be hauled with special permits which require additional administrative work.

To be air transportable in a C-130, the unit must fit into a space 10 ft wide, 41 ft long and 9 ft high and weigh less than 35,000 lb.

Because of these restrictions, the design maximum size for a mobile laboratory is 40 ft long and 8 ft wide, 105 in. high, and it must weigh less than 35,000 lbs. Since not all of the equipment needed for the water-analysis laboratory can be placed in a laboratory of these dimensions, the water analysis laboratory should be built to the maximum size. The air-analysis laboratory requires less space and could be somewhat smaller. Neither laboratory will be limited by the weight restriction.

In addition to the size limitations, the mobile laboratory and the equipment therein should meet the general specifications for air transportability as given in MIL-A-8421-C. These requirements are more severe than those required for surface transportability and indicate the most severe conditions met in air travel. Standard commercial practice is to pack in the same manner for both truck and air transport. Section 3.3.3 of MIL-A-8421-C, flight and taxiing loads, reads

> "The equipment shall withstand, without loss of serviceability, an acceleration of 3g for a minimum of 3 seconds applied independently along each of the longitudinal and vertical axes in each direction, and 1-1/2g for a minimum of 3 seconds applied independently along the lateral axes in each direction."

Section 3.3.4, emergency landing loads, reads

> "Equipment shall be designed to withstand the following loads encountered in crash landings without any of the major components of items being transported breaking loose. The item need not be serviceable after being subjected to such accelerations:
>
> a. A minimum of 9 g in either direction applied independently along each horizontal axis for a minimum of 3 seconds. When the equipment is of such size or configuration that it can be loaded into cargo aircraft with only a particular axis

parallel to the longitudinal axis of the aircraft (i.e., a truck that can be driven forward or backed into the aircraft), the 9g requirement need be met in both directions along this particular axis (i.e., long axis of the truck). When the loading direction is fixed or specified for an item (i.e., a truck that can only be driven forward into the aircraft), the 9g requirement need be met only the forward direction and a 2g requirement shall be applicable in the rearward direction.

b. A minimum of 4-1/2g vertically downward for a minimum of 3 seconds in such a direction that equipment carried in a cargo compartment imposes a load on its wheels or supports in a downward direction."

These specifications indicate that everything in the laboratory must be adequately fastened down during air transport.

Three basically different shell-types were considered: (1) a laboratory mounted on a self-propelled vehicle, (2) a laboratory mounted in a trailer which could be pulled on its own wheels, and (3) a laboratory without wheels that would be transported on a truck or aircraft. In the order listed, the laboratories required more outside support in shipping and less maintenance. Table I lists shells of each type and presents dimensions and costs for the laboratory shell when used for a water analysis function and for an air analysis function.

Self-Propelled Laboratory

Self-propelled units were considered only briefly in both bus- and truck-mounted units. However, all units, which might have been considered for a mobile laboratory, were more than 9 ft high and thus were too high to be transported by C-130. Truck-mounted units, because

TABLE I. COMPARISON OF SHELLS FOR MOBILE LABORATORIES

	Moving Van-Fifth-Wheel Trailer	House Trailer	Goodyear Expandable Shelter
Available			
Length, ft	Up to 45	Up to 60	13
Width, ft	8	8,10,12,14	8 Closed 21 Expanded
Height, ft	Up to 13	Up to 12	8
Minimum Floor Height, in.	22-5/8	25	8
Carrying Capacity, lb	45,000	12,000 est.	8,000
Water Laboratory Design			
Length, ft	40	40	13
Width, ft	8	8	8-21
Height, in.	104-1/2	104-1/2	96
Weight, empty, lb	11,000	6,000	4,000
Weight, loaded, lb	27,000	18,000	12,000
Special Equipment for loading in C-130	dolly, ramp	ramp	forklift
Running Gear	9.00-15 tires Tandem dual	8.25-15 tires Tandem dual	none
Meets Military Specifications	No	No	Yes
Cost $	14,000	7,000	15,750
Air Laboratory Design			
Length, ft	28	26	13
Width, ft	8	8	8-21
Height, in.	104-1/2	104-1/2	96
Weight, empty, lb	8,000	5,000	4,000
Weight loaded, lb	11,000	8,000	7,000
Special Equipment for loading in C-130	dolly	ramp	forklift
Running Gear	9.00-15 tires Single axle-Dual	8.25-15 tires Tandem single	-
Meets Military Specifications	No	No	Yes
Cost $	13,000	5,000	15,750

of the drive shaft under the laboratory, would have the laboratory floor at least 3 feet above ground. The 6 feet left for headroom, roof thickness, and clearance between the unit and C-130 is obviously inadequate. Buses mounted on a truck frame would have the same problem and mass-produced transit-type buses were 10 ft, 1 in. high. Retooling for a lesser height would be prohibitively expensive.

Trailer-Mounted Laboratory

Two types of trailers were considered: (1) the ball-hitch trailer commonly used for mobile homes which has a set of wheels just to the rear of its center of balance, and (2) the fifth-wheel semi-trailer used by commercial freight companies which has a set of wheels near the rear of the trailer and a substantial part of the weight is on the pulling tractor. Four-wheel trailers were not considered in detail because of (1) difficulty in backing such a unit, and (2) the fact that a fifth-wheel semi-trailer can be converted easily into a four-wheel trailer so that the design developed for a semi-trailer unit would also be adequate for design of a four-wheel trailer.

Ball-Hitch Trailers

Ball-hitch trailers are made in a variety of sizes up to 60 ft long and 14 ft wide. An 8- by 40-ft trailer was considered for the water pollution laboratory and an 8- by 26-ft trailer for the air-pollution laboratory. Many companies make trailers of this type for homes and offices and because of intense competition one could be obtained to desired specifications. However, all trailers observed on the sales lots were judged to be too weakly constructed and the running gear was judged inadequate for Air Force mobile laboratory service. This may reflect a lack of experience in manufacturing heavy-duty equipment. The major advantage of a ball-hitch trailer is that all of the space is

usable as compared with the large area of limited utility in semi-trailers. The major disadvantages are that the load must be reasonably well balanced over the wheels and that the trailer would be difficult to load in a C-130. A special ramp would be needed to load the trailer. In addition, the unit lacks adequate headroom.

This type of trailer would not meet military specification primarily because the specifications are not applicable to vehicles with this type of running gear. The ball-hitch is not mentioned in the specifications. The trailer would be equipped with four or six wheels and specifications for vehicles with this number of wheels assume that the wheels will be placed at the ends rather than in the middle and, therefore, provides an impossible requirement for steering capability.

Other deviations from military trailer specifications necessary for a mobile laboratory include:

> Specification Mil-M-8090-E, Section 3.3.9. The equipment is required to negotiate a 20° ramp. A layout indicated the ground clearance necessary to meet this specification with a 40-ft ball-hitch trailer is more than 7 ft.
> Section 3.16.2. Tires should be of a size specified in Table V of this specification. Either 8.25-15 or 9.00-15 tires would be specified because of the low floor level required. Neither are listed in the table but are in general commercial use for the intended loads.

Semi-Trailers

Semi-trailers are made in 8-ft widths and lengths up to 45 ft. The floor of a standard semi-trailer is about 4-1/2 ft above the road and with 9 ft of clearance in the C-130, the interior height would be limited to less than 4-1/2 ft. Therefore, a standard trailer is impractical. A moving van type semi-trailer might be used since the floor of one model of a van is designed to be 25-5/8 in. above the road and can be lowered by 3 in. by using smaller wheels and tires. By

layout a moving van can house a laboratory with 78 in. of headroom and can be loaded into a C-130 with some difficulty by using special equipment. A special dolly to lower the front end for loading on a C-130 would be needed to provide extra overall height. A ramp would be needed to afford adequate ground clearance during loading. Also the roller conveyor 463L system normally in the C-130 would have to be removed to provide an additional 2 in. of headroom. The 463L system could be stowed under the moving van during flight.

A laboratory in this type van would have an advantage over all the mobile laboratories visited in that it would be close to the ground; thereby making access to and loading of the laboratory easier than access to and loading of the Army or EPA laboratories.

Moving vans are built in many standard designs. Single and tandem axles are available, leaf and air-cushion springs are available, the van can be made in almost any length and height, doors can be placed anywhere except the front center, the van can be insulated as specified, and the tire and wheel size can be varied. The maximum drop (the distance between the floor over the fifth wheel and the floor in the body of the trailer) available in a standard unit is 27 in. With this drop a crank-type axle is necessary to provide a level floor between the wheel wells. Drops of 24 and 13 in. are available using standard axles. An empty 40-ft trailer weighs about 11,000 lbs. and costs from $7,000 to $15,000 depending upon extras. The estimated cost of the van (an insulated shell on wheels with doors) was $14,000.

A single-axle dolly with a rigid fifth wheel was needed to load the van into a C-130 aircraft. The dolly could be towed behind the trailer in highway service and also could be used to carry the ramp. Tandem axle dollies were normally used only for greater than anticipated loads.

Deviations from military trailer specifications necessary for a mobile laboratory in a moving van include:

1. Specification Mil-M-8090-E, Section 3.3.9, stated that the equipment be designed to negotiate a 20° ramp. On a 40-ft trailer about 31 in. of ground clearance was

required with optimum rear axle placement. The trailer was designed for 15 in. of ground clearance when hitched on a tractor, and 12 in. of ground clearance when supported on a dolly for loading into the C-130.

2. Section 3.5.1.2.1.2.2 stated that the required kingpin vertical location is 50 + 1-0 in. This dimension was designed to be 44 in. Since the kingpin height on a tractor was not adjustable, the trailer sloped toward the rear in transit. When loaded on the C-130, a 42-in. high kingpin will be used on the dolly so that the trailer sloped toward the front.
3. Section 3.16.2 stated that tires should be of a size specified in Table V of this specification. The 9.00-15 12-ply tire selected was listed for use only in low-speed service. However, this tire was listed by the Tire and Rim Association for high-speed service at the anticipated load.

Other military specifications that would be difficult to meet include:

1. Specification Mil-A-8421, Air Transportability, stated that the mobile laboratory must withstand without damage 3g's in all directions except sideways; the sideways acceleration requirement was 1-1/2g. The loaded vehicle must withstand a 9g acceleration without breaking the cargo tie-downs or releasing material and equipment inside of the laboratory. It also requires that the laboratory be loadable in the C-130. We judged that the mobile laboratory in a moving van type trailer would meet these specifications, but to our knowledge, this has not been demonstrated.
2. Mil-Std-1472 requires a minimum headroom of 78 in. in a laboratory mounted on wheels. This standard can be met only if the 463L gear is removed from the C-130.

C-130 Modifications for a Trailer

At present almost all C-130 aircraft have been equipped with a 463L material handling system, which was built into the floor of the cargo bay. This system reduced the cargo bay clearance from 9 ft to about 8 ft, 9 in. Wheeled vehicles were difficult to load with this cargo handling system in place. The trailer design was made assuming the 463L system would be removed from the aircraft during laboratory transport.

Expandable Shelters

Goodyear Aerospace has developed and is now producing expandable shelters for the Air Force which might be applicable as a mobile laboratory. Their basic unit was 8 ft wide by 8 ft high by 13 ft long in the closed or transport mode. In the expanded mode, the unit was 8 ft high by 21 ft wide by 13 ft long. The inside container dimensions in the closed mode were 7 ft wide by 12 ft, 4 in. long by 80 in. high. The basic unit costs $15,750 and is now in production in Akron, Ohio. The system was designed to be loaded into the C-130 with the 463L system of roller conveyors which were built into almost all C-130 aircraft. The basic unit weighed about 4,000 lbs. and can be used for a container of an additional 8,000 lbs. For mobility, it could be loaded into the C-130 or onto a flatbed truck or onto a railroad car with a 10K forklift which is available at all airbases. Mobilizers, wheels which convert the unit into a four-wheel trailer were available for movement on a base if special provision was made for them. While these units with mobilizers were approved for highway use, they did not appear practical in that application.

In addition to this logistics model, a personnel module was available. Since it contained only 75 cu ft of storage space in the collapsed condition, the personnel module would not be applicable to a mobile laboratory. If the logistics module were used, it should be the production model which is modified after receipt.

Additional specifications for the logistics module were:

(1) 208-120-volt, 4-wire, 3-phase, 60-amp power input (this was adequate for the laboratory and reported to be Air Force standard power.

(2) Polyurethane floor, which could be vinyl covered.

(3) Alkyd painted walls.

(4) The aluminum skin thickness was 0.040 in. inside 0.050 in. outside.

(5) Passed a 21-in. drop test without damage in the loaded condition.

(6) Passed a 9g force test, without rupture.

(7) Had forklift provisions from either side or either end.

(8) Erection time by unskilled labor was one hour by four men.

(9) The unit had four fixed windows and choice of door configurations.

(10) The heat transfer coefficient through the walls was 0.3 Btu/hr-^{o}F-ft^{2}.

(11) The unit had a phone connection and external light.

(12) Maximum floor loading was 120 psf in the core section and 80 psf in the expanded section (a doubling plate could be used to decrease point floor loadings).

(13) An air conditioner-heater unit was available, 60,000 Btu heat, 3-ton air conditioning, and double units could be used.

(14) Three units could be carried in one C-130 or on one flatbed truck.

(15) The cargo doors were 4 ft wide.

(16) Two ventilation fans were installed.

RECOMMENDATION FOR SHELL AND INTERIOR DESIGN

Shell Evaluation Rationale

The commercial type trailer unit was preferred and the Goodyear expandable shelter was second choice. The house-trailer type unit possibly could be used, while a self-propelled unit was rejected because none could be transported in a C-130 because of overall height limitations. The commercial trailer was preferred to the house trailer because:

(1) Commercial trailers are normally constructed to more rugged specifications

(2) A lower floor is available in a commercial trailer, thereby giving greater headroom in the van

(3) Loading of equipment into the commercial trailer is not critical as to weight distribution because the trailer is greatly overrated for load while the house trailer must be carefully loaded to maintain a reasonable hitch weight

(4) The commercial trailer carries a greater load

(5) The time of day of house trailer movements is limited

In turn, the house trailer was preferred to the commercial trailer because:

(1) The house trailer contains more space

(2) The initial cost is less.

The first five factors were judged more important than the latter two factors. The more rugged construction may mean that the commercial-type trailer would outlast several house trailers and thereby might offset the cost differential. The greater headroom in the commercial trailer will allow better placement of lights and ventilation ducts and make for a better laboratory layout. At this stage of the design it is an intangible factor but as the laboratory is used it will be appreciated by the workers. Slightly greater worker efficiency during the life of the

trailer could more than compensate for the cost differential between the trailers.

Proper load distribution on a house trailer could be a problem and shifting of the load after tie-down could be expensive and time consuming. Delays necessitated by shifting of the load could be expensive if men were kept waiting.

The greater load carrying capacity of the commercial trailer meant that more equipment could be carried in the trailer. With present type missions either unit could carry the anticipated load. However, if the scope of the mission were increased, or if heavy apparatus were added to the present list of equipment, the house trailer could not carry the increased load. For the air-quality trailer the demand was less critical since the equipment loads were less.

The front 8 ft of the commercial trailer was not useable as laboratory area because of the higher floor over the fifth wheel. The area was used partially by placing a bench at the front of the trailer floor and by placing utilities which require little adjustment in the part of the truck without headroom. However, some floor space was lost and a house trailer could be used for about a 10 percent greater mission than a commercial trailer if floor or bench space were the limiting factor. The cost of the trailer shell would be a small part of the cost of the mobile laboratory and an almost trivial part of the cost of missions which would use the trailer. Therefore, the shell which allowed best mission performance would be best on a cost basis. On an overall basis the commercial trailer was substantially better than a house trailer.

The comparison between the Goodyear expandable shelter and the commercial trailer was somewhat more difficult since the units are quite different. Either would be a good choice and the problem was to define the preferred choice.

Table II is a comparison of the laboratory housed in expandable shelters or in semi-trailers. If enough units were used the laboratory could be housed in either. Both were judged to be much better than the present setup in which the equipment was boxed and sent to a base. The

TABLE II. COMPARISON OF SEMI-TRAILER LABORATORY WITH EXPANDABLE SHELTER LABORATORY FOR EHL-KELLY

		No. of Expandable Shelters						No. of 40-ft Trailers			Mission			
		1	2	3	4	5	6	1	2	3	Small	Normal	Max.	Projected
Load capacity, lb		8000	16,000	24,000	32,000	40,000	48,000	50,000	100,000	150,000	5000	10,000	16 000	25 000
Bench length, installed, ft		24	48	72	96	120	144	64	128	192	40	80	150	250
Bench length, temporary, ft		48	96	144	192	240	288	0	0	0				
Floor area, ft^2	Closed	90	180	270	360	450	540	240	480	720	200	400	700	1500
	Expanded	260	520	780	1040	1300	1560							
Volume, ft^3	Closed	600	1200	1800	2400	3000	3600	1600	3200	4800	400	600	1000	1500
	Expanded	1800	3600	5400	7200	9000	10800				1500	2500	5000	10.000
Cost, dollars		16,000	32,000	48,000	64,000	80,000	96,000	14,000	28,000	42,000	---	---	---	---
No. of aircraft or trucks for shipment		1	1	1	2	2	2	1	2	3				

table shows that the semi-trailer had the advantage on a dollar basis, on weight hauled, permanent bench space, floor area, and volume. The major advantage of the expandable shelter was in shipment. Three units, which have a greater laboratory capability than one semi-trailer can be shipped for about the same effort as the one trailer, that is on one flatbed truck or in one C-130 aircraft.

Another advantage of the shelter is that it will meet all military specifications. The semi-trailer will not meet the specification of negotiating at 20° ramp. This specification should be waived for the laboratory because no need for climbing a 20° ramp is foreseen. In addition, the trailer has not demonstrated its air transportability as required by specification. However, the trailer is judged to be capable of meeting these specifications. On a dollar basis the semi-trailer is judged to be better than the expandable shelter for use as a mobile laboratory.

SPECIFIC INSTRUMENT CONSIDERATIONS

The most important elements of the mobile field laboratories, aside from equipment essential for laboratory operation, are the instruments used to make the analytical measurements on samples gathered during the daily operation. The Environmental Health Laboratories at Kelly and McClellan Air Force Bases already had in use many such instruments and were constantly evaluating others for their adaptability to mobile laboratory operations. Those chosen were done so judiciously because they met requirements of detection limits, accuracy, cost, size and weight, ruggedness, and reliability, and were deemed suitable for use in the mobile laboratory. As the scope and extent of field surveys change, these evaluations should be continued and selections will be based on suitable criteria to permit evaluation of potential new or replacement instruments. These criteria may include space saving or reduced manpower requirements. Skilled workers in the field become accustomed to instruments through an

understanding of their operation and maintenance, and acquire an intuitive feeling for evaluating subsequent systems. Hence, they provide added experience in the selection of new or replacement equipment for the mobile laboratories.

Water Quality Instrumentation

The Environmental Health Laboratory at Kelly AFB concerned itself primarily with wastewater quality when doing field survey studies. The instruments used in such studies are given in Table III. The field unit operation required separate chemical assay and bioassay facilities to avoid interference by chemicals in the bioassays. Each facility should be self-contained and independent even though some duplication of instrumentation was apparent. Bioassays required only minor amounts of analytical instrumentation but relied heavily on pumps and recorders and extensive equipment for use outside of the mobile laboratory. Therefore, an instrumentation selection or evaluation rationale would be straightforward.

Chemical Analysis Instrumentation

General Considerations

To limit doubt and ambiguity of the analyses of water and wastewater by chemically related methods, a standard set of procedures used by essentially all workers in this area should be used. Such procedures have been given in the manual "Standard Methods for Examination of Water and Wastewater" (Ref. 1). Use of such procedures enhances acceptance of results and permits comparisons to be made. Good sampling techniques, however, are essential for meaningful water quality evaluation. The use of instrumental methods of analysis not specifically defined in the manual are, in general, acceptable providing the results so obtained are checked periodically each day, either against a standard method

TABLE III. LIST OF FIELD SURVEY INSTRUMENTS USED BY ENVIRONMENTAL HEALTH LABORATORY, KELLY AFB: WATER QUALITY FACILITIES

Model No.	Function or Use	Dimensions, lxdxh, in	Power Required, v-a or watts	Accuracy or Precision Ranges	Cost, $ Est.	Cost, $ Cat.	Auxiliary Equipment	Maintenance, Spare Parts	Spec. Tools	Ease Calib.	No. Req.	Special Comments
Ionics, 225	Oxygen Demand (TOD)	46x26x36	1800	$\pm$20%			Cyl. N_2, compressor				1	
Balance Mettler, H10T	Solids etc.	10x20x16	120v-0.2a	$\pm$0.1mg		915	Weights for calib check	Tared dishes	No	Exel	2	Requires stable stand
Spectrophotometer Bosch & Lomb, spectronic-20	MBAS Phenols	16x13x8	120v-135w	$\pm$0.5%		495	Sample cells	Photomult. tube, source lamps	No	Exel	1	Electronic voltage regulation desired ruxiliary equip for cont recording
Turbidity Meter Hach 2100A	Turbidity Chloride detn.	12x9x8	120v- 30w	0.05FTU		475	Sample cells		No	Exel	1	
pH Meter Beckman	Acidity (CN^-)	16x24x96	120v- 15w	0.05pH unit (0.01 pH expand)		375	Glass elec. Buffer soln	Electrodes	No	Good	1 1	Other electrodes suited for ion analysis (e.g., CN^-)
Hydro Ion Test		16x24x16	15w								1	
O_2 Analyzer Yellow Springs Inst. 54	Dissolved O_2 BOD	12x6x8	25w	0.1ppm		620	Battery and charger	Membranes		Good		
Atomic Absorption Varian Techtron, 1000	Heavy metals	72x15x16		0.1ppm	8000		Hollow cathode tubes, recorder source O_2, N_2, & C_2H_2, power supply			Good	1	
Recorders, Rustrak	Temperature DO		150w			300	TC, O_2 Probe	Chart and paper	No		7	
Sterilizer, Autoclave Castle		18x30x20	2500w			788					1	
Calculator, H-P Algebraic-9000 10A			110v- 15w		2000				No		1	

described or a standard of undisputed composition. Those instrumental methods reviewed and evaluated as acceptable by the Standard Methods manual include: atomic adsorption spectroscopy, flame photometry, emission spectroscopy, polarography, potentiometric titration, specific ion electrodes and probes, gas chromatography, and automated analytical instruments. Such instruments save time and reduce manpower requirements once their reliability has been established.

Atomic absorption has been accepted as a standard method for most heavy metals. Specific ion electrodes were less acceptable, except for fluoride ion and dissolved oxygen measurements, because of varying degrees of interference from other ions in the sample. Their use in monitoring, however, has gained acceptance. Gas chromatography is rapidly gaining acceptance for analysis of chlorinated hydrocarbon pesticides and sludge digester gas.

Automated analytical instruments required a fair degree of operator skill and knowledge together with adequately detailed instructions and standard procedures. They were attractive despite their high cost since automated instruments performed analyses on 10 to 60 samples per hour for 2 to 12 constituents. Each component analyzed required its own module. Each module was joined through flexible tubing, and performed individual operations of filtering, heating, digestion, time delay, color sensing, etc., required by the analysis. The methodology employed for water and wastewater was supplied by the manufacturers. Some methods were identical to the standard methods, others were not. An appraisal of the method was mandatory, since methods varied in reliability. Unsuspected interferences that cause color change or turbidity normally caught by the analyst in conventional techniques often go unnoticed and give erroneous readouts. Therefore periodic and systematic calibration were essential for reliable information (and an added task for an already busy field team).

Any future generation instrumentation being considered for use in the mobile laboratory will have to bear a burden of parallel analyses using a standard method until all ambiguity is removed. Such time is not

always available in the field and will have to be a function of the base laboratory.

Adaptability of Existing Instruments for Mobile Laboratory Use

The adaptability of the instruments already in use by the Air Force in field water-quality measurements for air transportability and for use in the modular concept were determined through contacts with manufacturers. A summary of the findings are given in the following paragraphs.

Spectronic 20 (Bausch & Lomb). The Spectronic 20 cabinet could be mounted on a bench top permanently or stored in a padded drawer or in its own shipping carton (foamed polystyrene) during transit. Mounting on the bench top requires a special base plate to which the spectrophotometer is attached through the three base feet. The plate and spectrometer would then have to be secured to the bench top to ready a module for transit. The simplicity of the instrument and the small amount of set-up time required to put it in operation would justify its storage in a bench drawer properly padded for all possible movement. These units are shipped to jobbers in special foamed polystyrene cases packed in cardboard boxes. The packages have met National Safe Transit Committee guidelines and have undergone shake table tests equivalent to 1000-mile truck trips and 1.5-ft drops on all six sides and four corners and still operated. It is estimated that during the drop test the instrument undergoes forces of anywhere from 1.5 to 9 g. These units have been shipped via air freight by laboratory supply dealers. No components need to be removed during transit. Assembly and warm up would be required during conventional operation.

Mettler Analytical Balances, H-31 (formerly H-10). The balance can be secured firmly to the bench by means of brackets and bolts fastened to the base and attached to existing legs. For operation these brackets must be loosened and the balanced leveled. For transit the beam and the weights must be locked in place. This is done with a set of 12 screws each contained in the balance and not removed during weighing operations. The procedure can be quickly learned by those using balance. The cycle requires about 5 to 10 minutes. The Bureau of Mines, U.S. Department of Interior, carries such a balance for demonstration purposes in a wooden case and rely only on these screws to secure the balance for shipment. Balances in Mettler's own packing are shipped via air freight without any special preparation for the low pressures or temperatures encountered in cargo holds. The pan should be removed and/or fastened by means of tape to balance body during transit.

Varian Instrument, Techtron 1000 Atomic Absorption Unit. Shell and cabinet are rugged and claimed to survive the 3 g forces anticipated in air transport. Cabinet has been shock mounted for land mobile use in campers and other land-mobile laboratories. For air transport it was suggested that rubber feet should be removed and the base fastened permanently to bench top by means of angle braces and bolts. If desired (but not deemed essential) a shock mounting employing a steel wool cushion can be used. Varian has transported the Techtron 1000 in a wooden box (into which it fits snugly and is retained in place with straps) to various seminar demonstrations throughout the U.S. and Canada. It is handled as luggage with no special precautions in handling requested. It is not labeled as an "instrument". For semipermanent mounting on bench tops, binder clamps or aircraft type fasteners were suggested.

Components that should be removed for air transport are: The burner head assembly, because it may float under negative-g forces. The hollow cathode lamps should be removed for any kind of transit and stored in their original shipment boxes.

Assembly and warm up of a mounted instrument should take less time than when equipment was packed in boxes.

Ionics 225, Oxygen Demand Analyzer (TOD). The cabinet as constructed and mounted securely to bench top by means of angle braces and bolts is expected to meet the 3 g forces anticipated during air transportation.

Components that should be removed and packaged prior to any form of transportation are:

Reaction chamber quartz furnace tube and catalyst.

Liquid electrolyte and gas bubbling parts of cell scrubber section. They suggested filling with distilled water during shipment; however, reduced pressures and cold temperatures anticipated during air transport will cause leakage and freezing. Best to carry empty.

Sampling valve should be removed.

Sliding doors should be fastened by a latch mechanism or by strong adhesive tape.

Reassembly will require at the maximum 0.5 hour. Spare parts should be on hand.

Warm up and equilibration will require the usual 4 hours encountered in start-up proqedure for this instrument (Ref. 13).

Hack, 2100A Turbidity Meter. This meter requires that it be mounted with shock mounting only if vibrations occur during operation of the instrument. The cabinet can be fastened to the bench top by means of brackets and bolts, or because of its convenient size, carried inside of a padded cabinet drawer of the module. About 4 inches of bubble padding are presently used for shipment via air freight.

The components that should be removed for transit are the sample cells, cell riser, and light shield. A spare lamp assembly as well as spare cells should be carried with the instrument. Because the stability of the secondary standards upon exposure to extreme cold is unknown care should be taken to avoid freezing of these solutions. They should be carried by the personnel or in an insulated container. Modest temperature cycles do not cause problems.

Assembly should require only a few minutes. The inherent drift of these instruments requires 12 hours of operation before restandardization can be eliminated before each reading.

Yellow Springs Instrument Model 54, Dissolved Oxygen Meter. This is inherently a rugged instrument and demonstration models have been transported as luggage in the cargo hold of airplanes throughout the country. Low temperatures may adversely affect the mercury or nickel-cadmium batteries if they are completely discharged. Cool batteries can be heated by charging them briefly prior to use. The only care that must be taken after air transit is that of remaking the probe assembly because the low pressures encountered at high altitudes forces the small amount of water in the probe to stretch the membrane. This operation is a routine maintenance operation. Because of its size, the instrument and probe can be stored in a padded drawer of the module cabinets.

Conclusions

We judge that at this time instruments currently being used for water-quality analysis to be adequate and suitable for obtaining data acceptable both technically and legally. These instruments are preferred and will be useful for producing unambiguous data in support of Air Force actions to minimize the environmental impact of base operations. These same instruments have been found to be adaptable to air transport if suggested mounting or storage procedures are followed. Instrument

manufacturers encouraged common sense in developing a module concept for transit and suggested adding fasteners, removing delicate components, draining solutions, and securing each item against the possibility of a negative gravity force. Certain instruments as they are presently manufactured will constantly be plagued with operational problems after transit. The total carbonaceous analyses employing infrared optics is an instrument in this category. In such cases it would be preferable to work with the manufacturer directly to develop a reliable and transportable instrument module than to attempt to modify an existing unit to meet the mobile laboratory requirements.

Total reliance on instruments for analytical data without manual back-up analytical procedures could halt a mission short of its goal in event of power outages or instrument failure. Therefore the availability of classical noninstrumental techniques for analyses should be provided for each module sent on a mission.

AIR-QUALITY INSTRUMENTATION

The instrument requirements used in air-quality monitoring in the field have not been as well delineated as those for water-quality evaluation, since no field surveys had been scheduled. From the information at hand it would appear that the analytical instrument selection task should be handled by the home base at McClellan AFB. The analytical instruments used for stack gas analyses consist of a gas chromatograph, analytical balance, and Orsat gas analyzer. Calibrated gas mixtures contained in cylinders are used as standards. A major portion of the equipment is used in sample collection of gases and particulates. When ambient air monitoring is performed in the field the instrument requirements are increased and include the following:

Nondispersive Infrared Analyzer for CO
Paper tape sampler for H_2S
Hydrocarbon analyzer for all hydrocarbons

Colorimetry for SO_2 analysis (WACO)

Coulometry for ozone analysis (MAST)

Meteorological instrumentation.

Again to produce results comparable with those obtained at other laboratories and legally acceptable, standard analyses must be used. The air analyses have been specified by the EPA in the Federal Register and are frequently updated (Ref. 2).

The McClellan laboratory built its own stack sampling equipment because the equipment was needed before commercial models were available. The commercial models are aesthetically more pleasing than the home-made units but use the same key components and provide equivalent analytical quality. While commercial units should be considered for additional equipment, there is no need to replace the present equipment related to stack sampling. The use of sampling equipment, however, is not without its problems and repair of glass components is frequently required to continue operation. Besides provisions for field repair, some provisions must be provided for calibration and evaluation of the performance of the sampling devices. Cylinders of calibrated gas mixtures are used for this operation.

McClellan Air Force Base also is responsible for noise measurements and this too requires little instrumentation in the field (tape recorder, noise level meter, etc.). New analytical concepts or instrumentation are continually being marketed for air pollution monitoring. The Environmental Protection Agency evaluates such instruments as part of its service. Their evaluation of instrumentation of interest to the McClellan EHL is discussed in the following section.

Selection of New Types of Air Pollution Instrumentation

The Environmental Protection Agency (EPA) is engaged in research programs to develop improved instrumental methods to measure atmospheric pollutants. As new instrumental concepts in air pollution monitoring

reach a stage of development where they show potential of providing reliable measurements, the EPA evaluates their performance under field conditions. The testing programs attempt to identify weaknesses in the monitoring principal and design and makes appropriate adjustments where possible.

They have recently reported on the results of ambient measurements of oxides of nitrogen (NO_x), ozone (O_3), sulfur dioxide (SO_2), carbon monoxide (CO), methane (CH_4), and nonmethane hydrocarbons made with new instrumental procedures in field tests. Instrumental methods evaluated included gas phase chemiluminescent methods for measuring O_3 and NO_x (nitrogen dioxide and nitric oxide), gas chromatographic methods for measuring SO_2, CO, CH_4 and total hydrocarbons, coulometric methods for measuring NO_x and SO_2, and flame photometric measurements for measuring SO_2 (Ref. 14).

The operational characteristics of the air pollution monitoring instruments listed in Table IV used during the field evaluation program are given in Table V. (Mention of the company names or commercial products does not imply endorsement by the EPA or Battelle.) Instruments with rapid response times and low sample flow requirements were noted as especially desirable operational characteristics.

The findings on NO_x and SO_2 measurements are of specific importance to the Air Force Environmental Health Laboratories. The evaluation revealed the following:

(1) The Beckman coulometric measurements for NO_2 were significantly lower than measurements with a chemiluminescent monitor during peak concentrations. However, where mean concentrations of NO_2 for 24 hours were below 0.1 ppm, an agreement of better than 90 percent of absolute concentration of NO_2 could be obtained among the Jacobs-Hochheiser, Saltzman colorimetric and chemiluminescent methods.

TABLE IV. INSTRUMENTATION AND MEASUREMENT METHODS

Pollutant	Analyzer or Method	Principle of Operation[a]
Nitrogen dioxide	Beckman 910	Coulometric
	Thermo Electron NO_2	Chemiluminescent
	Technicon NO_2	Colorimetric (Saltzman)
	Jacobs-Hochheiser	Manual-colorimetric
Nitric oxide	Aerochem NO	Chemiluminescent
	Thermo Electron NO	Chemiluminescent
Sulfur dioxide	Meloy SO_2	Flame photometric
	Tracor GC-SO_2	GC-flame photometric
	Philips SO_2	Coulometric
	Pararosaniline	Manual-colorimetric
Ozone	Bendix O_3	Chemiluminescent
	Mast Oxidant	Coulometric
	Technicon IV	Colorimetric
Carbon monoxide	Beckman 6800	GC-FID
	MSA CO	NDIR
Total hydrocarbons	Beckman 6800	GC-FID
	Power Design Pacific	FID
Nonmethane hydrocarbons	Beckman 6800	GC-FID

(a) GC--gas chromatographic; FID--flame ionization detector; NDIR--nondispersive infrared.

TABLE V. OPERATIONAL CHARACTERISTICS OF AIR POLLUTION MONITORING INSTRUMENTS

Analyzer	Setup Time, min	Warmup Time, hours	Lag Time, min	Rise Time, min	t_{95}, min	Range, ppm	Flow Rate, liters/min
Bendix O_3	30	0.5	0.08	0.17	0.25	0-0.5	1.50
Technicon IV A (O_x)	60	1.0	2.60	3.3	5.9	0-0.5	0.51
Mast Oxidant	45	1.0	0.20	3.5	3.7	0-0.3	1.14
Power Design Pacific (THC)	--	--	0.2	0.6	0.8	0-20	0.03
Beckman 6800 (THC, CO, CH_4)	240	24.0	2.50	(a)	2.5	0-10, 0-10, 0-10	0.01
Beckman 910 (NO_2)	45	2.0	0.40	5.4	5.8	0-0.5	0.15
Aerochem NO	120	24.0	0.08	0.17	0.25	0-1.0	0.01
Thermo Electron NO, NO_x	60	24.0	0.17	0.25	0.42	0-1.0	0.40
Philips SO_2	30	0.5	0.70	2.4	3.1	0-0.2	0.15
Meloy SO_2	45	1.0	0.10	1.0	1.1	0-0.5	0.20
Tracor GC-SO_2	210	12.0	3.00	(a)	3.0	0-1.0	0.01
MSA CO	--	--	0.40	0.6	1.0	0-50	1.50

(a) Not applicable.

(2) Chemiluminescent ozone and NO_2 monitors as well as the coulometric SO_2 analyzer exhibited excellent zero and span stability.

(3) Carbon monoxide concentrations measured gas chromatographically were 3 to 6 ppm lower than values obtained with a nondispersive infrared analyzer.

(4) Coulometric and flame photometric measurements had correlations of better than 0.874 with the West-Gaeke colorimetric method for monitoring SO_2.

Specifically the following comments were made about the instruments evaluated in the field:

Nitrogen Oxide Monitor. In general, the Beckman 910 coulometric analyzer recorded concentrations of NO_2 lower than the Beckman (a prototype), Thermo Electron, and the Aerochem chemiluminescent monitors. There was excellent correlation between the latter two for NO_2 concentrations. The Beckman prototype is designed to operate at 460 torr rather than 1-5 torr pressure, thereby reducing pumping requirements and pump maintenance.

Sulfur Dioxide Monitors. The flame photometric detector (Meloy), the coulometric analyzer (Phillips), and gas chromatographic monitor (Tracor GC) displayed similar diurnal patterns. Only the coulometric and total sulfur flame photometric detector gave good (0.874) correlation with the West-Gaeke procedure. Poore correlation of the gas chromatographic flame photometr detector analyzer was related to electronic and flow problems that occurred sporadically. The manufacturer plans to make modifications suggested by the EPA to correct these deficiencies.

Ozone and Oxidant Monitors. The oxidant monitors (Mast) generally recorded concentrations close to the values

obtained with chemiluminescent ozone monitors (Bendix) during periods of peak ozone concentrations.

Carbon Monoxide. The nondispersive infrared analyzer (MSA) gave CO concentrations 3 to 6 ppm higher than gas chromatograph-flame ionization detector (Beckman 6800) due to electronic drift and/or interferences in the NDIR analyzer.

Field ambient air monitoring activities at Battelle's Columbus Laboratories (BCL) have employed chemiluminescent techniques for oxides of nitrogen. BCL has found that commercially available instruments are inadequate for field operation and usually they have to be modified or rebuilt to obtain reliability. Such equipment is usually replaced with instruments built by the technical staff (Ref. 15).

ANALYTICAL INSTRUMENTATION AND EQUIPMENT STORAGE MODULE DESIGN FOR WATER QUALITY LABORATORY

General Consideration

Because of the design constrains of the mobile laboratory, it was impossible to provide a design in which space could be provided for all the desired chemical and physical analyses in a single unit. Also, most, if not all, missicns do not require every field analysis that should be available. In order to provide flexibility and to facilitate the installation of the required equipment, a modular design approach was taken. The modules were positioned along the walls of the shell. A module has been designed for each of nine analyses. Each module provided storage for the required glassware, tubing, chemicals, etc., as well as mounted large equipment, such as the TOD meter. The module also included any built-in equipment which speeded the installation or eased the performance of the desired operation while attempting to retain a degree of

flexibility. These nine modules can be used as a basis of design of additional modules.

While each module can be removed from and replaced with other modules, a module was installed relatively permanently to meet the specifications for air transportability described earlier. Also both land and air transport imparted a long-term vibrational load to the equipment which tended to loosen nuts. Therefore, lock nuts, lock washers, or other locking devices were needed on all fasteners.

Since most of the modules were made from laboratory cabinets, Figure 1 shows the attachment of a laboratory cabinet to the trailer. The permanent sinks and benches would be attached similarly. It is important to note that the attachments were to the logistic posts and to the floor I-beams rather than to the wooden wall or floor because the wooden structures might not be capable of restraining the equipment against the loads given in Specification MIL-A-8421C.

Most modules were built from standard laboratory cabinets which were available from many manufacturers. Differences between manufacturers were minimal and the cabinets were specified by length, width, height, and drawer configuration. Cabinets for stand-up work were specified as 36 in. high and for sit-down work as 30 in. high. The mobile laboratory used 24-in.-wide counter tops which was the width most commonly used in chemical laboratories. The drawers in these units were 18 in. deep and in the closed position were 2 in. from the laboratory wall. A 3-in. deep by 6-in. high kick space provided for toe room. The cabinets were built to length using 6-in. increments. For ease in loading and unloading, the longest cabinet specified was 48 in. long. A cabinet was normally bolted to the adjacent cabinets and this practice should be followed in the mobile laboratory. While the cabinets were fastened to the trailer with slotted angle in Figure 1, reasonable alternate arrangements would be equally satisfactory.

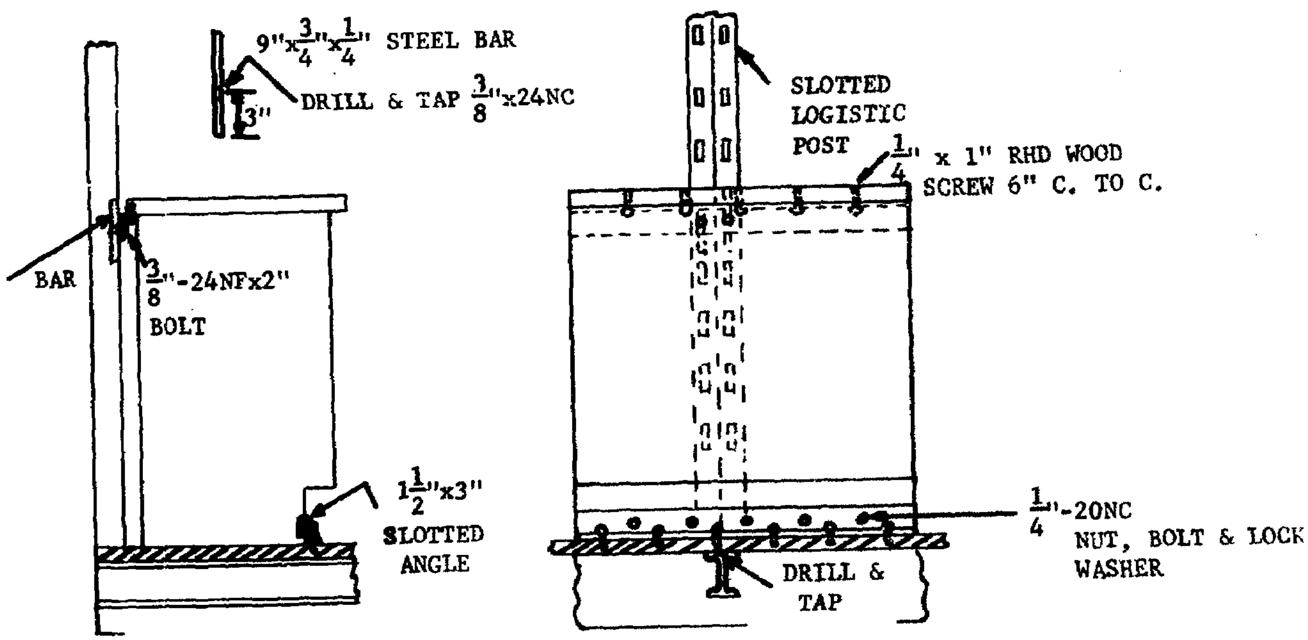

FIGURE 1. FASTENING DETAILS

Biochemical Oxygen Demand (BOD) Module

The Biochemical Oxygen Demand (BOD) module, Figure 2, provided space for three 100-bottle capacity BOD incubators and for work space needed for the preparation of the sample and subsequent analyses. As shown in Figure 2, one incubator will be placed on top of the other with a mounting arrangement to hold the two units together. The height of the top unit may provide some inconveniences, but the design is based on the most efficient space utilization. The third unit will stand by itself, equipped with a plastic top to provide the required working space.

Phenol Module

The phenol module, Figure 3, provided space for 8 distillations and 12 extractions along with bench space for chemical handling, etc. The entire module required 8 ft and three cabinets. The first cabinet was provided primarily for distillation (although the front bench space would also be used in the extraction step). The built-in rack held 8 variable transformers. Because of the required configuration for the distillation operation, the heating mantels were placed to the rear approximately 2 ft above the working surface. The transformer rack fitted under the heating mantles. The floor flanges permanently bolted to the cabinet top provided quick assembly of the equipment. In addition, if phenol analyses were not performed, the space could be used for other purposes. The large cabinet, 47 in. long, standard height and width, was necessary to store the distillation equipment, ring-stand type rods, the portable separatory funnel holder, as well as other large equipment.

The two other cabinets provided the needed work space for the extraction step. The built-on separatory funnel holders provided for efficient space utilization as well as convenience in operation. Standard 2-ft cabinets were employed because of their mobility and the necessity to provide a total of 8 ft of bench space.

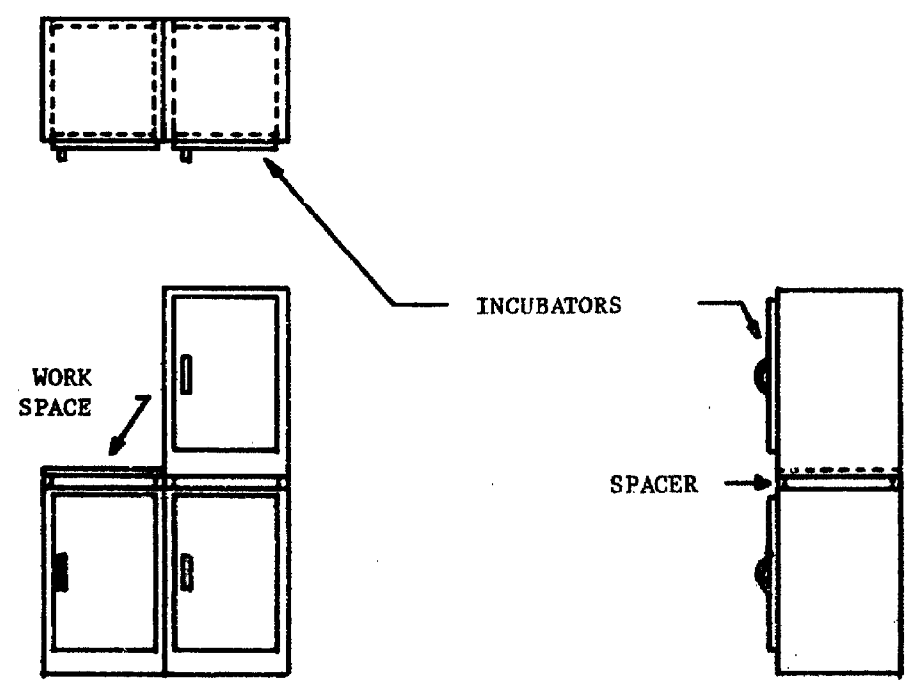

FIGURE 2. BIOCHEMICAL OXYGEN DEMAND MODULE

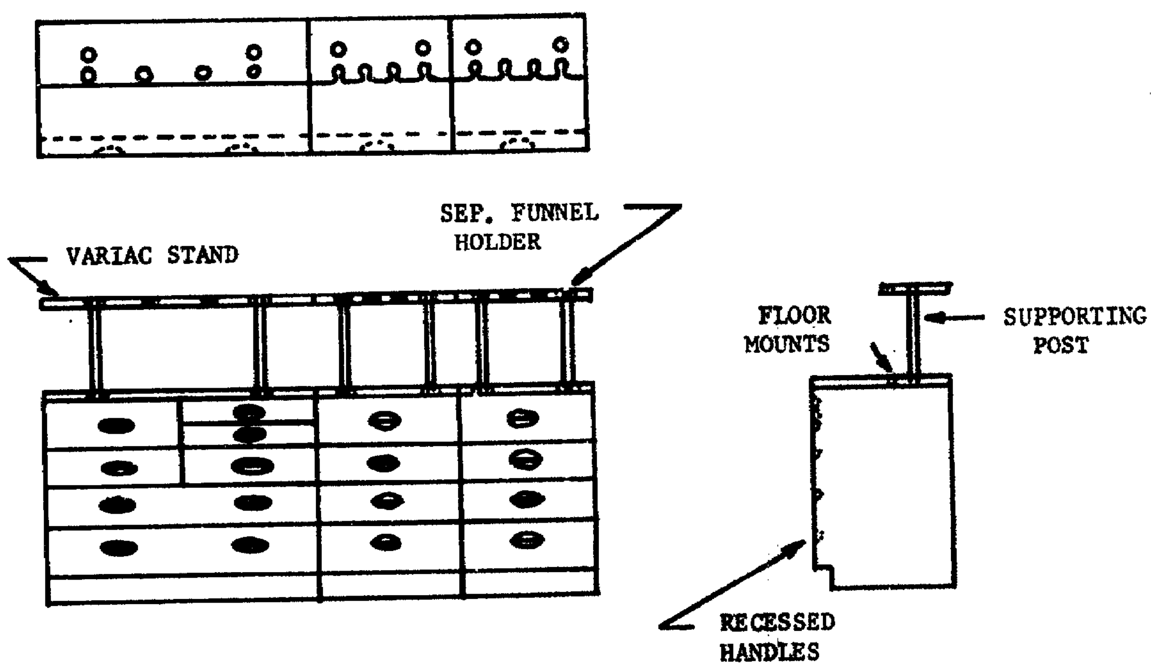

FIGURE 3. PHENOL CHEMISTRY MODULE

Methylene-Blue Active Substance (MBAS) Module

The methylene-blue active substance (MBAS) module, Figure 4, for determination of surfactants from detergent production was the largest module, requiring a total of 12 ft of floor space. The facility provided space for 18 separatory funnels, a general working area, and space for the photometric determinations. The first three cabinets, 35 in. long each, were identical, providing adjustable racks for 6 separatory funnels, 1-1/2 ft of work area, and a variety of storage space. The spectrophotometer was mounted on the fourth cabinet. Two large doors instead of drawers were utilized in the fourth cabinet providing flexibility to meet different storage requirements. Additional racks were mounted on the wall. The module, while providing built-in conveniences, could be easily modified to provide facilities for new requirements or analyses because of its simplicity.

Chemical Oxygen Demand (COD) Module

The chemical oxygen demand (COD) module, Figure 5, provided built-on heating facilities for 12 reflux operations, floor flanges for mounting equipment, as well as needed working space on two identical 30-in.-long cabinets. The built-on design allowed for easy operation, ease in transport, and quick assembly. Large cabinet drawers were specified to hold the reflux condensers, volumetric flasks, burettes, etc.; smaller drawers were specified to hold the COD flasks and other small equipment.

Total Oxygen Demand (TOD) Module

The Total Oxygen Demand (TOD) module, Figure 6, provided a cabinet to mount the equipment and a small amount of working space and storage facilities. A large cabinet was necessary because of the size of this

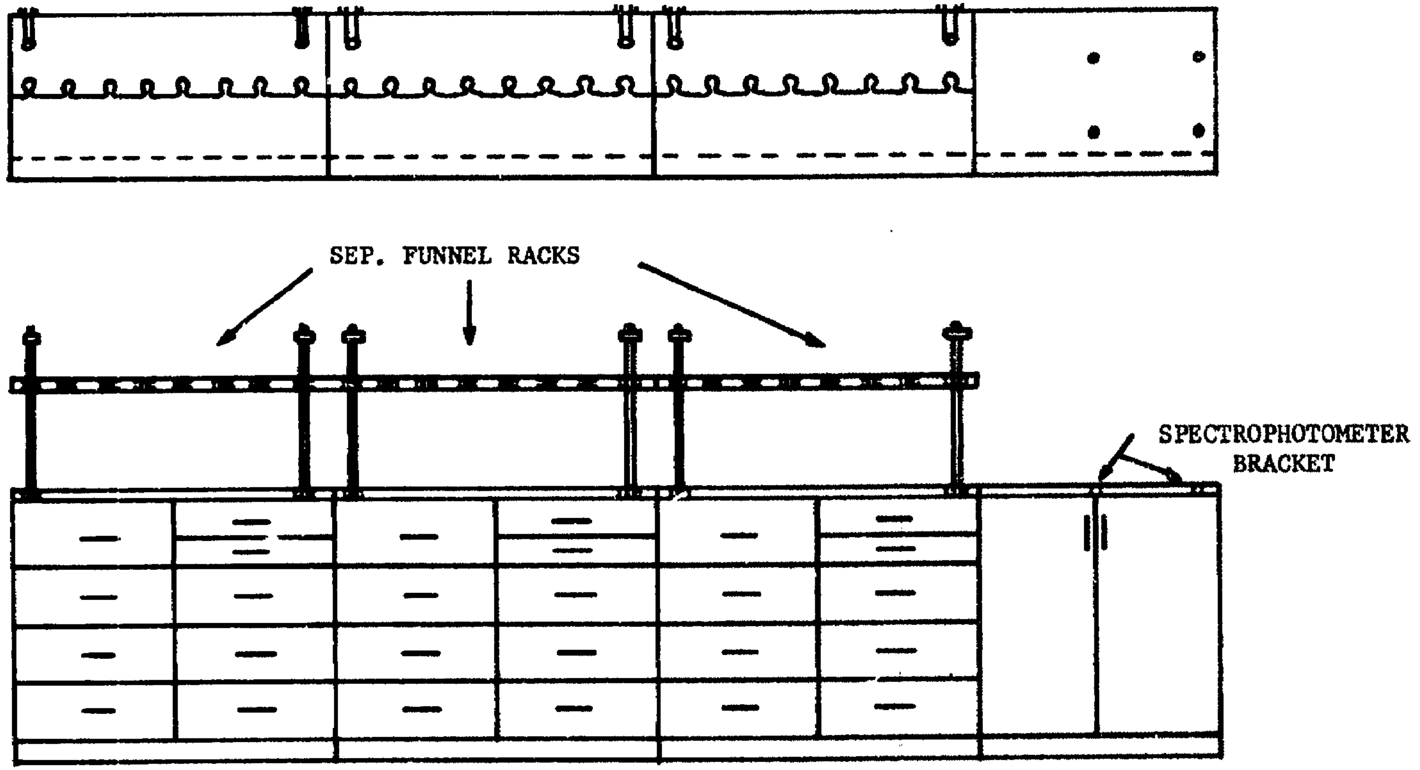

FIGURE 4. METHYLENE-BLUE ACTIVE SUBSTANCE MODULE

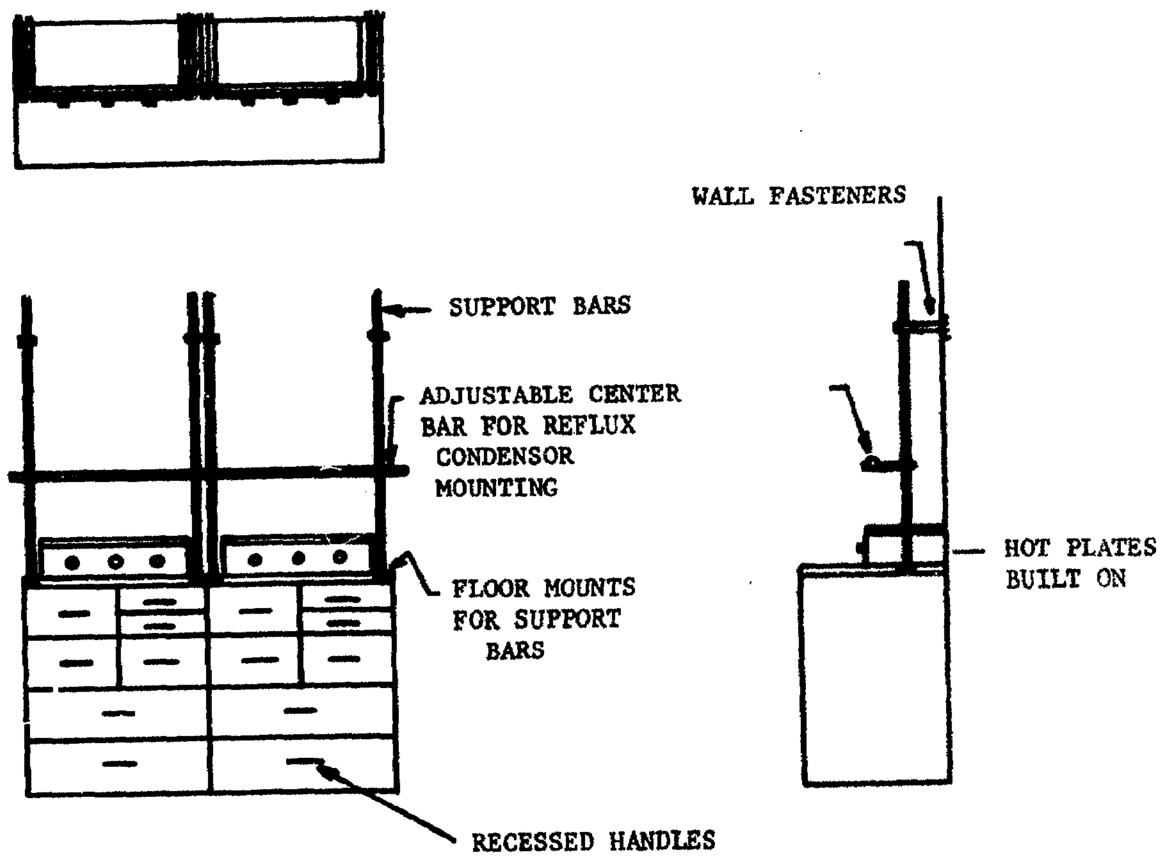

FIGURE 5. CHEMICAL OXYGEN DEMAND MODULE

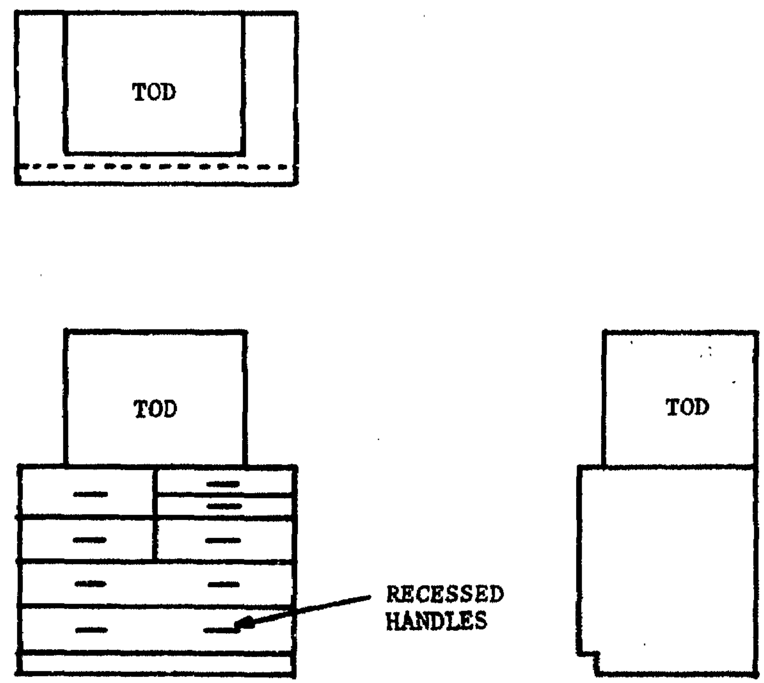

FIGURE 6. TOTAL OXYGEN DEMAND MODULE

instrument. Another arrangement could be employed in a situation where modular space was limited. Instead of a module, the instrument could be boxed for transport and simply set up on one of the workbenches. The amount of equipment required for this operation is minimal, therefore, the cabinet drawer configuration specified was designed to allow flexibility for storage of equipment other than that required for the TOD determination.

Heavy Metals Module

The Heavy Metals module, Figure 7, provided space to mount the atomic absorption (AA) unit, space for the recorder and sample holder, as well as working space. The module consisted of two 35-in.-long cabinets. The AA unit was placed upon one unit, allowing working space in front and to the side of the unit. Mounting the unit on top of the cabinet was specified to keep the entire operation on one level, to provide easy access to an exhaust source for removal of gases from the AA, and to simplify the plumbing necessary for the nitrogen, oxygen, and acetylene supply. The second cabinet provided adequate area for the recorder, sample holder, chemicals, etc., and storage area for these and other heavy-metal determination equipment. In addition, space was available to store equipment not related to this operation. The configuration specified was intended to provide flexibility in meeting storage requirements.

Coliform Module

The coliform module, Figure 8, provided space for a sterilizer, an incubator, for sample preparation, and for storage. Legs were attached to the incubator to raise its top surface to bench level. A 24-in.-long cabinet furnished the necessary working area. The drawer configuration provided flexibility in meeting storage requirements.

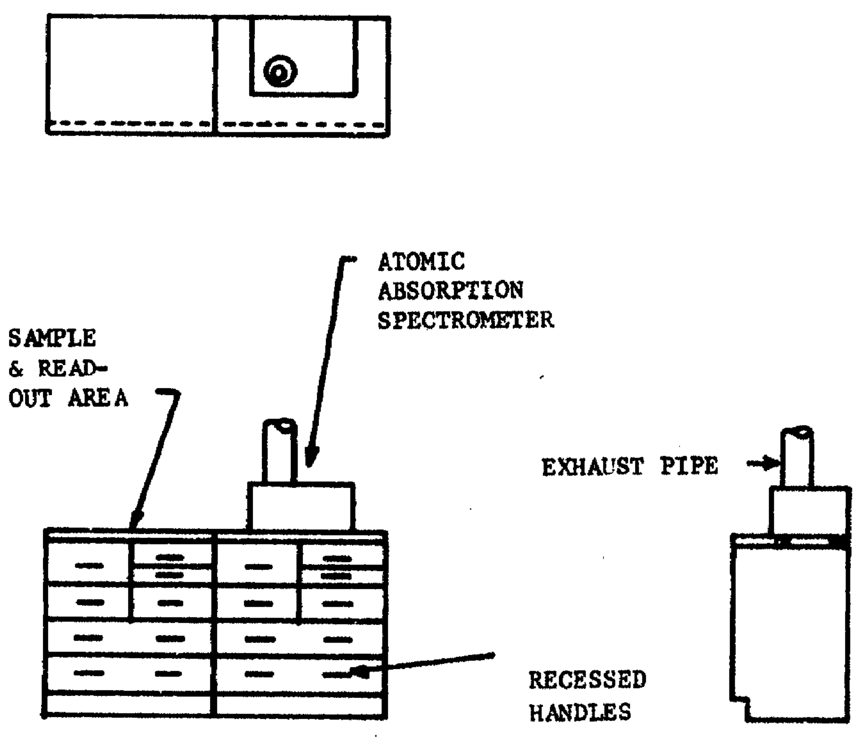

FIGURE 7. HEAVY METALS MODULE

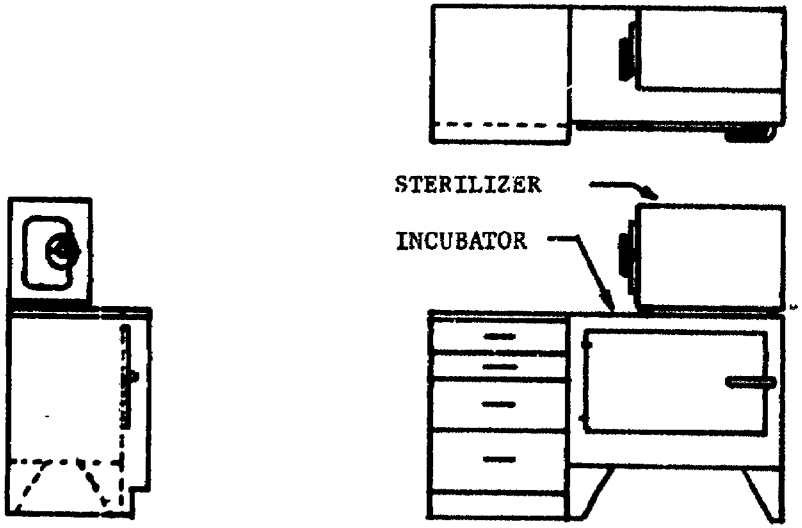

FIGURE 8. COLIFORM MODULE

Common Specification Considerations

All bench and module tops were constructed from a laminated hardwood base with 1/16-in. thermosetting plastic. This plastic resists concentrated acids and other corrosive materials for short durations, weaker acids for extended periods. In addition, the wood-plastic top was chosen because it is lighter, less expensive, and easier to install than either chemical stone or stainless steel.

Other specifications common to all cabinets included recessed handles and locks with a common key on all drawers. Recessed handles were necessary to prevent breakage during loading those items stored in the center aisle. Locked drawers have been found to be necessary to keep drawers from coming open during transport.

Other Analyses

Additional analyses such as total solids, total dissolved solids, suspended solids, and total volatile solids could be performed with equipment which can be fastened to the benches and did not require individurl modules.

Analyses which could be performed with meters, by titration, or with equipment already built into other modules would be performed where space was available. These included determinations such as alkalinity, cyanide, hydrogen ion, turbidity, chloride, color, total hardness, etc. Since little setup time was required for these analyses, the lack of a module was not a disadvantage.

Bioassay Modules

The bioassay modules were designed to meet less specialized requirements than those for the water-quality laboratory modules. These modules provided storage space for chemicals and bulky equipment and

additional working area. Large cabinets with chemically resistant tops were specified. As shown in Figure 9, 17 ft, 3 in. of storage-module space was allocated along one side of the trailer. It used five, 35-in., and one, 24-in. double-door cabinets.

Along the opposite wall, a desk and cabinet, as shown in Figure 10, were fitted into the space available. The desk provided file and drawer space for coordination of the field and laboratory operations. The cabinet provided storage space for large equipment and working area for additional bioassay functions.

Ambient Air-Sampling Module

The ambient air-sampling module, drawn in Figure 11, was a rack made of 1-1/2 by 3-in. slotted angle 9 ft long, 5 ft high, and 2 ft deep. The back was bolted to the logistic posts in the wall and the bottom was bolted to the I-beams under the floor. The back uprights were set 3 in. from the wall to allow the water and air lines to pass behind the rack. Uprights and laterals on the rack front were set to accommodate the analytical instruments and recorders and could be modified easily for mounting of replacement or additional equipment. The recorders were at the top for easy reading. The rack height was limited to 5 ft because of lights and duct work immediately above the rack. Clamps for tie down of three cylinders were mounted at each end of the rack.

UTILITY REQUIREMENTS

In addition to the specific analytical equipment, any laboratory must be supplied with utilities. The utilities designed into the laboratory included hot and cold water, sinks, electric power, purified water, compressed air, heating, cooling, and ventilation. Safety equipment could be considered as part of the utilities.

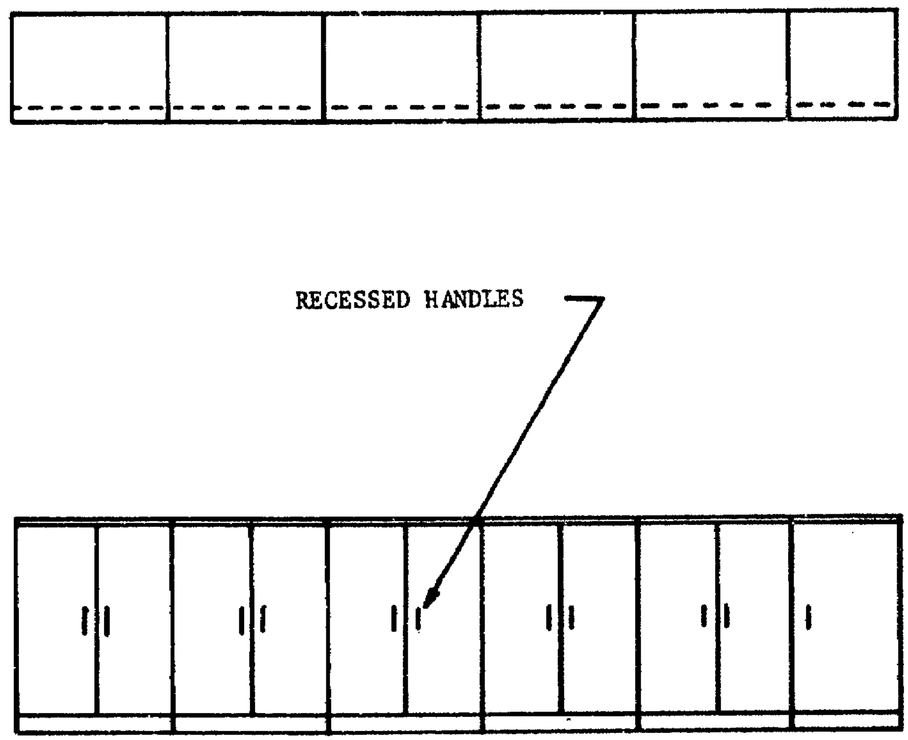

FIGURE 9. BIOASSAY MODULE

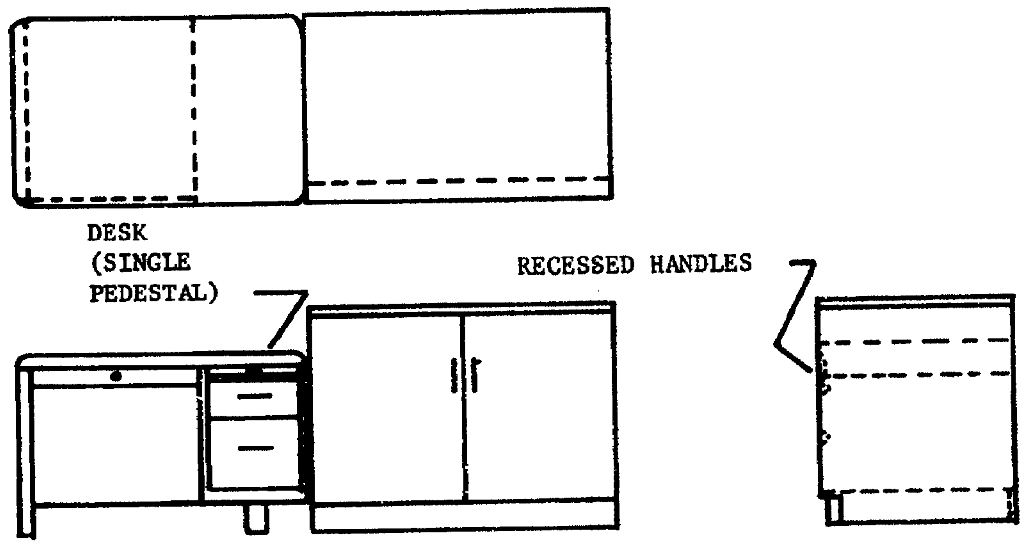

FIGURE 10. DESK MODULE

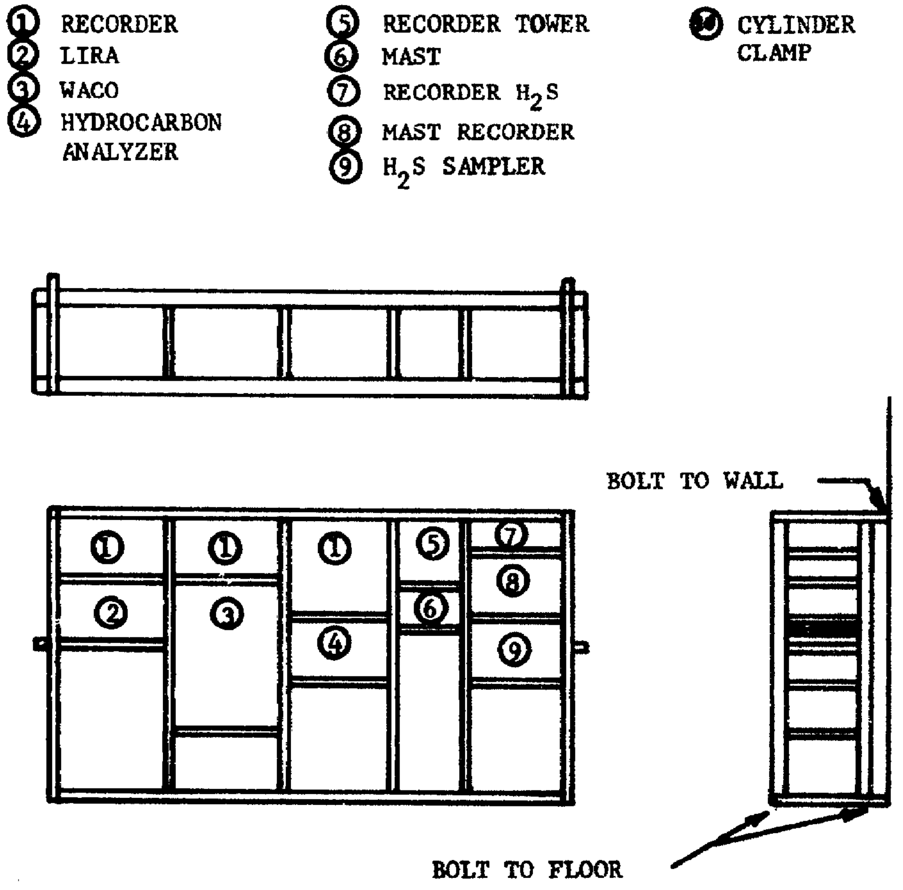

FIGURE 11. AMBIENT-AIR MONITORING MODULE

The water requirements were nominal, mostly for washing equipment and cooling water for analytical equipment. A hose connection to the base supply was adequate as a hose supplied about 3 gal/min. The hot water was required primarily for washing equipment. A 50-gal tank capable of heating 28 gal per hr with a 100 degree rise was specified and should be more than adequate for the need. The cabinet type was specified so it would fit in the nose of the trailer. Two sinks were specified for washing dishes. Stainless steel bowls were specified.

The electric power requirements for the laboratory include a number of items. Air conditioning and space heating are the major power users, and it was fortunate that both were not needed at the same time. About 25 kw were needed for laboratory equipment, mainly through convenience outlets. About 27 kw were needed for the space heater, 20 kw for the air conditioner, 7 kw for the water heater, and about 2 kw for lights. The peak demand was therefore about 60 kw. This required a 250-amp service on single-phase, 3-wire, 240-120-volt systems and 170-amp service on 3-phase, 4-wire, 208-120-volt service. Since Air Force power was usually 208-120-volt 3-phase, and at off-base locations the power supply was probably 240-120-volt single phase; the inlet box must be designed to accept either power source. Equipment rated at 240 volts should be specified to work on two legs plus neutral of a 208-volt 3-phase supply. Such equipment was usually available, but not normally supplied unless specified.

Purified water was supplied with a 4-cartridge demineralizer. One cartridge was needed to demineralize water and two cartridges were needed to remove organics from water at a flow of 20 gal/hr. Because of the high flow rating, storage would not be needed. Space for a fourth cartridge was provided for either special polishing of the water to remove a particular impurity which may be upsetting an analysis or for an additional cartridge to demineralize water so that cartridges need not be changed quite as frequently. Each demineralizer cartridge purifies about 100 gal of very hard water. Each organic removal cartridge treats about

1500 gal of water. The organic cartridge also removes chlorine. Two cartridges were needed to obtain flow capacity. The alternate system employed a still. A complete distillation system was slightly more expensive than the demineralizer; however, stills have a low throughput or require a very large electric power supply, since about 3 kw-hr are needed per gallon of water. Therefore, a large storage tank would be needed with a still and the space required would be somewhat greater than with a demineralizer. Both demineralizer and distillation systems produce water acceptable for most analyses and water which requires additional polishing for a few analyses. A polishing step might be easier to conduct with the demineralizer because a special cartridge could be used to replace one of the demineralizer cartridges in a four-holder system. Many different cartridges are made for different kinds of polishing and the cartridge selected depends upon the water supply and the water use.

The compressed air requirement was small and primarily for instrument cooling, activation of some instruments, and drying of equipment. Most small air compressors capable of providing 120 psi pressure would be acceptable. The air probably should also be used to blow out water lines before transportation of the mobile laboratory so that water does not freeze in the water pipes.

The heating and cooling requirements are given in Table VI, assuming a most severe cooling condition of: 100° F and 80 percent humidity, sun on the laboratory, 20 kw of heat from equipment in the laboratory, and a hood drawing 500 cfm through the laboratory. The laboratory air is at 80° F and 50 percent humidity. This requires about 180,000 Btu of cooling. However, since a peak load of this type is not expected frequently and at high temperatures air conditioners pump more heat than their rating, the specification was reduced to 144,000 Btu. In the winter with similar air flow through the hood, no sun, and with a 70° F temperature rise, about 80,000 Btu per hour of heat is needed. A heater of this capacity was specified. Equipment in the laboratory will further heat the trailer.

TABLE VI. HEATING AND COOLING LOADS ON TRAILERS

	ΔT, °F		Chemical Analysis Unit, Btu/hr	
	Winter	Summer	Heating	Cooling
Roof	70	100	2,200	3,200
Sunny wall	70	50	2,000	1,400
Shady wall	70	20	2,000	500
Floor	70	20	2,200	500
Infiltration air			75,000	100,000
Occupant heat at 750 Btu/hr			--	7,500
Power heat			--	70,000
Total load, Btu/hr			83,400	183,000
Electrical demand, Kw			25	25
Outside temperature, °F	10	100		
Outside humidity, percent	--	80		
Inside humidity, percent	--	50		

Heat conductivity of wall, 0.1 Btu/hr-ft^2-°F.

Electrical resistance heaters.

Electrical refrigeration.

The ventilation was mainly through the hood and should be at least 500 cfm to remove vapors from chemical analyses.

Additional ventilators were provided for use in mild weather.

The safety equipment required for the laboratory included a fire blanket, two fire extinguishers, and nonskid steps and flooring near the doors.

DETAILS OF MOBILE LABORATORY

The requirements for both the air and water quality laboratories were similar and both laboratories were designed using a common shell with common utilities. Presumably the requirements of laboratories for other purposes similarly could use the same shell and utilities. The major difference between the laboratories was in the analytical instrumentation requirements, and most of this instrumentation was mounted in modules.

The laboratories were designed into a trailer 40 ft long with tandem axles. This length was the longest that fitted into a C-130. A shorter trailer would cost about the same, but provide less space. A tandem axle was chosen primarily because it gave a softer ride than a single axle. The tandem axle also permitted greater loads in the trailer. With present missions, a single-axle trailer would have carried the air-quality unit but not the water-quality unit. Figure 12 is a layout of the mobile laboratory. Sinks, deionizer, and a bench were provided on the curbside of the laboratory, other benches were provided on the road-side and front of the laboratory. Heater, air conditioning, hot water, and compressed air facilities were placed in the nose of the trailer. The spaces marked modules are spaces for specific instrumentation.

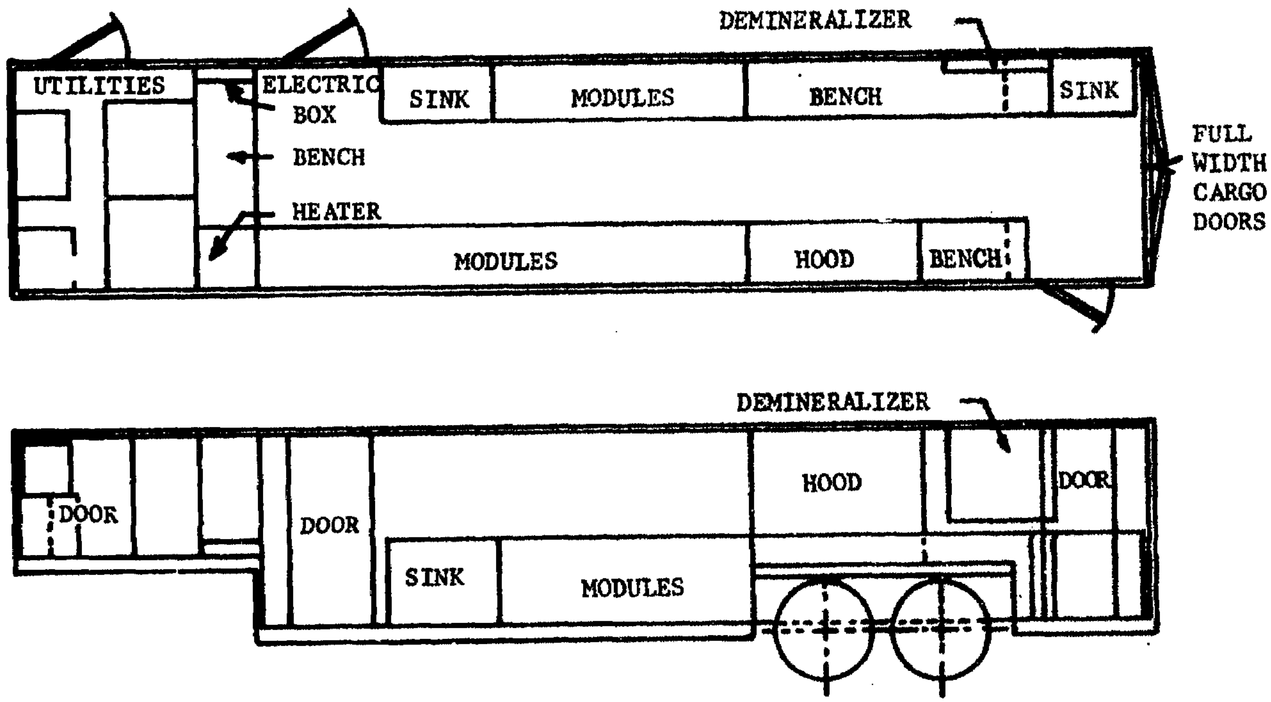

FIGURE 12. LAYOUT OF MOBILE LABORATORY

DESIGN OF AIR-QUALITY TRAILER

Figure 13 is a module arrangement which might be used in the air quality laboratory. The curbside was devoted to stack sampling re-requirement, a long bench, and a sink. The hood on the roadside was also needed for stack sampling. Glass-blowing equipment could be shipped in the cabinets and mounted on the benches at the test site. The roadside was primarily for ambient-air sampling. Most of the equipment was rack mounted and the rest could be shipped in the trailer and set on benches. The benches on both sides could be used to recharge batteries in portable equipment.

DESIGN OF WATER-QUALITY LABORATORY TRAILER

The water-quality sampling operations were varied in character and each mission required a somewhat different arrangement. To provide maximum flexibility only the utility functions were built into the laboratory. The analytical functions were built into modules (one for each analysis) which can be chosen for the individual mission and placed in the mobile laboratory. If facilities are available at the base visited, additional modules could be carried in the aisle of the laboratory and set up on that base. From the description of missions obtained in the trip to Kelly, only small-type missions could be housed in one trailer. Therefore, at least two and maybe three trailers should be purchased now and possibly additional trailers later when the mission size increases.

Table VII lists analyses performed in water-quality laboratory and the estimated bench or module length needed for each analysis. A total of 169 linear ft of bench or module is needed if all analyses were performed on one mission. The recommended laboratory design contained about 26 linear ft of module and 26 linear ft of bench space. Therefore, a laboratory on a mission using all capabilities of the water-quality

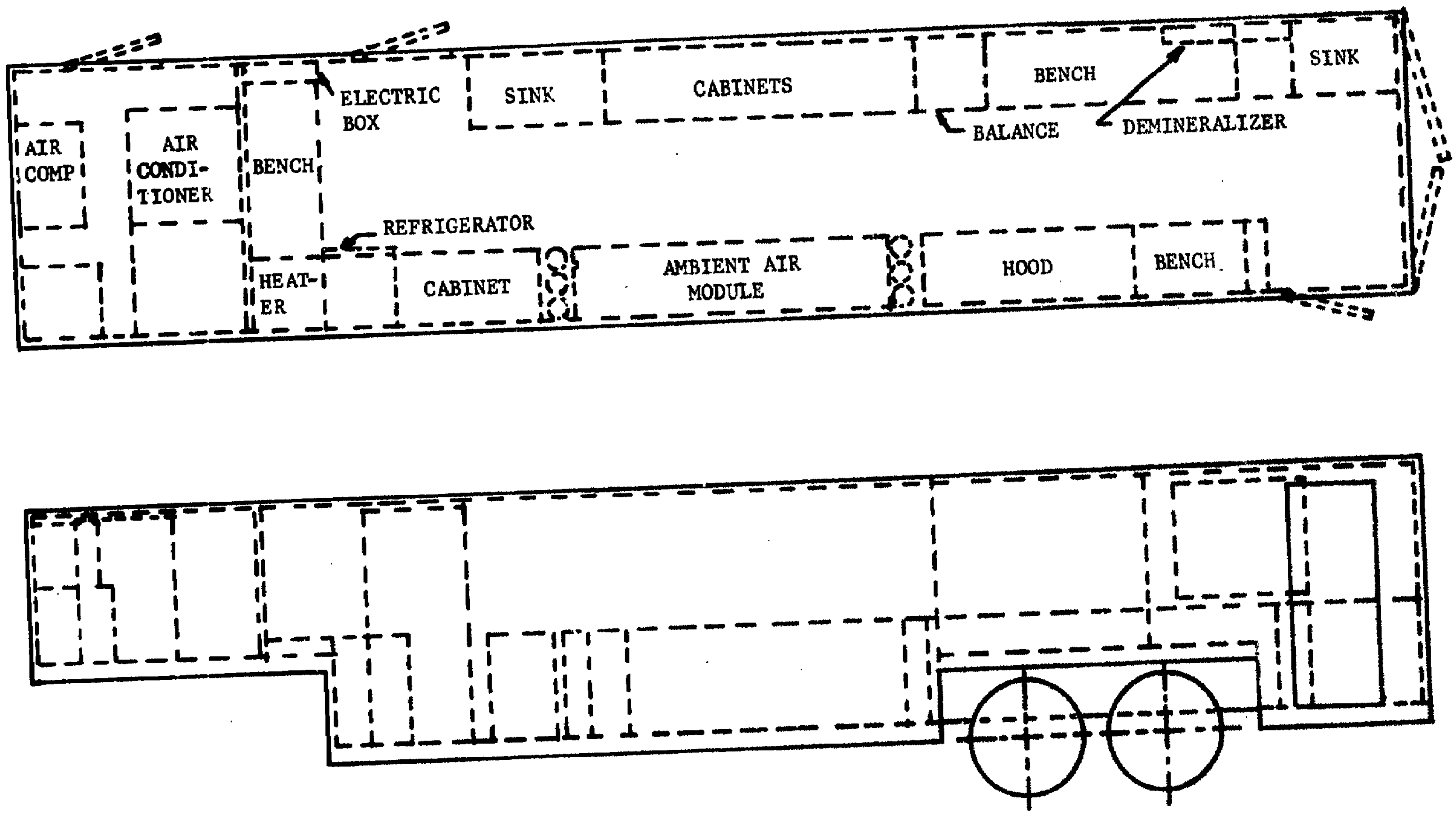

FIGURE 13. MODULE ARRANGEMENT IN AIR-QUALITY LABORATORY

TABLE VII. BENCH SPACE REQUIRED FOR WATER-QUALITY LABORATORY

	Bench Space, linear ft
Chemical Analysis	
TOD	4
COD	5
BOD 5	6
BOD 5, sol.	1
Solids	8
MBAS	12
Phenol	8
Turbidity, Cl^-	2
pH, CN^-	2
Coliforms	5
Heavy metals	6
Oil and grease	12
Nitrogen	8
Phosphorus	10
TOC	6
Sample preparation	10
Bioassay	
Fish	3
Daphnia	3
Aquariums	6
Dilution boards	6
Storage, cleanup	6
Battery recharge	6
Sewage Treatment	
Jar test	8
Battery recharge	6
Administrative	
Desk space	20
Total	169

laboratory would overflow three trailers. Presumably the requirements would be met partially by shipping equipment in the mobile laboratory and using that equipment in space provided by the base visited rather than by using four trailers.

A 40-ft trailer was chosen to house the laboratory because this was the largest size that can be loaded into a C-130. Tandem axles were specified because the anticipated load on the rear wheels was greater than 13,000-lb floor capacity for one axle of the C-130. Also a tandem axle gave a softer ride which was important when shipping the delicate instruments needed in the laboratory.

The modules, benches, and sinks were placed along the side of the laboratory because layouts of other arrangements were unsatisfactory. A U-shaped area for work with its own door was considered but found to have little more bench space than the one shown. Access between areas would have required leaving the laboratory and reentering, which was considered a disadvantage.

The module arrangement within the laboratory required some attention. All similar functions would be placed near each other. Exhaust fans would be built into the walls and equipment which releases heat would be placed near the fans. A possible arrangement for the modules in the water-quality laboratory is shown in Figure 14. In this arrangement, only the biochemical oxygen demand, the total oxygen demand, the chemical oxygen demand, and the coliform modules were placed in the trailer. The heavy metal analysis system was removed from its module and placed on the bench at the front of the trailer. Half of the methylene blue active substances module was in the laboratory. Many of the chemical analyses, all of the bioassay equipment, all of the sewage treatment equipment, and the administrative desks were omitted because of lack of space. Equipment for those functions would be shipped in the aisle space of the laboratory and set up in space provided by the base visited. Alternatively, up to four trailers would be used.

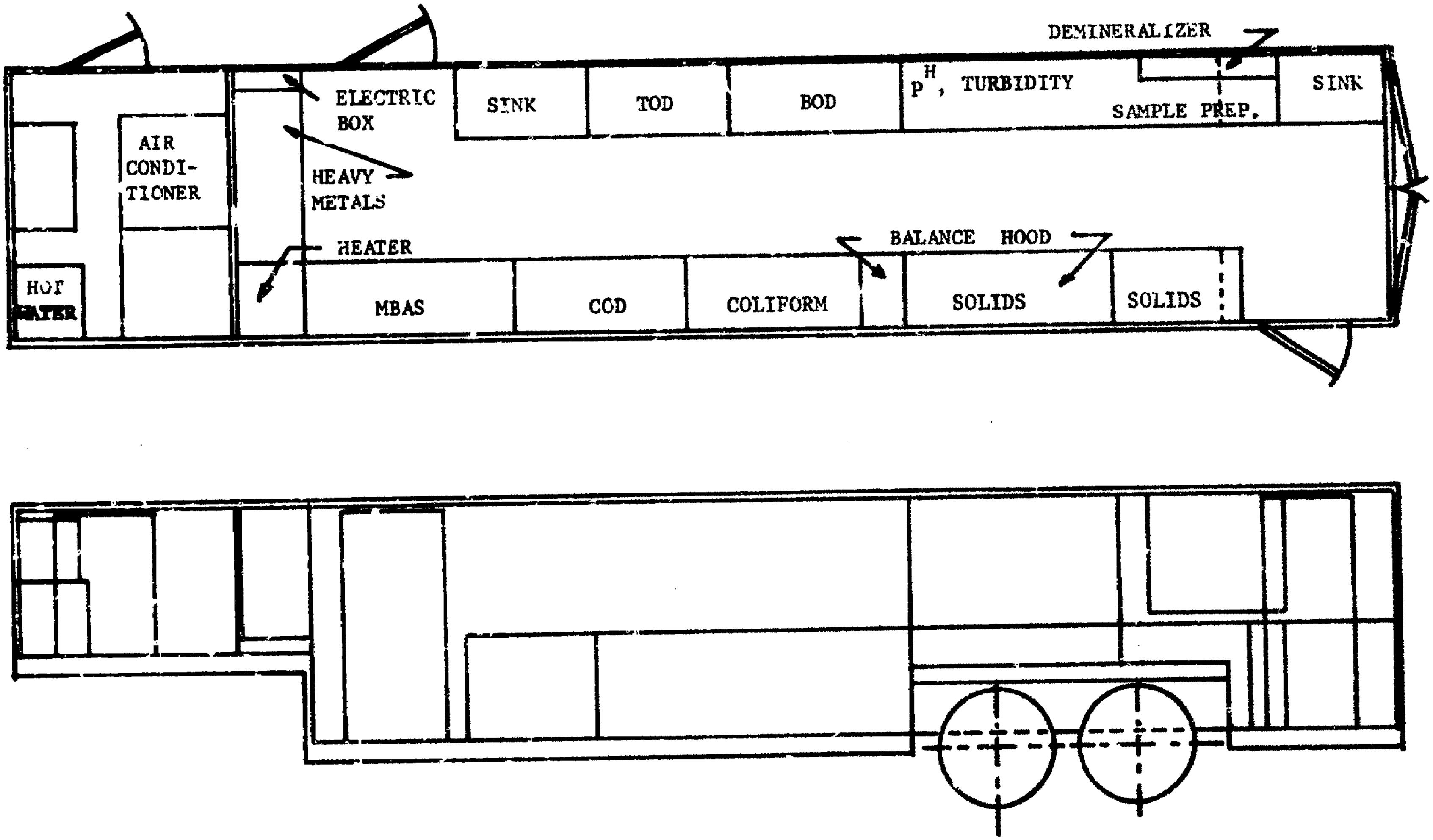

FIGURE 14. MODULE ARRANGEMENT IN WATER-QUALITY LABORATORY

Many other possible arrangements could be used and the actual arrangement should be tailored to the specific mission. The arrangement shown illustrates some of the options; for example, only half of the methylene blue active substance module is set up, and the heavy metal analytical equipment was removed from its cabinet module and set on a bench. It would be a mistake to consider the modular arrangement, or the modules themselves, as having an unchangeable design.

From the description of the typical mission of the water-quality laboratory, one trailer would be a considerable improvement over present practice, but the base visited would still have to provide substantial facilities. With two trailers, the help needed by the base visited would be reduced. With three trailers, all but the largest missions could be performed with only water, electricity, and sewage provided by the base visited. Four trailers were needed for using personnel on a maximum mission at maximum effectiveness without using building space at the base. Four trailers would also provide space for using the mobile laboratory at home base.

SECTION IV

OTHER POSSIBLE USES FOR AIR FORCE EHL MOBILE LABORATORIES

Air-transportable, land-mobile laboratories of the type being considered here for the Air Force Environmental Health Laboratories are capable of being modified for use in other types of emergency situations in which a well-equipped analytical laboratory is required in the field. Such situations may be related to Air Force and other Armed Forces emergencies or operations, and to national and international civilian emergencies. For example, at the site of a hazardous material spill caused by accident or act of nature (earthquake, severe storm, flood, etc.), a well-equipped field laboratory could provide data on which to base reparation activity by establishing the chemical nature of the hazard, the extent of encroachment on the environment, the countermeasures to be taken, and the effectiveness of the countermeasures being taken. Similar activities related to restoration of civilian water and sanitation operations after natural disasters in or near population centers are also envisioned. Under such emergency situations, the Air Force EHL mobile laboratory could be an integral part of the overall disaster team providing, by virtue of its air transportability, a rapid response capability presently not available. The same capability would provide the much-needed element of rapid response to natural disaster missions as well.

Although the mobile laboratories were designed primarily for water and air pollution studies, the modular concept used for equipping them provides flexibility to alter the interior of the laboratory by replacing one or more instruments or equipment functions for others that are best suited to the mission at hand. In anticipation of such ultimate utilization and newly strengthened and broadened capability through the use of mobile laboratories, the Air Force requested BCL to

recommend environmental emergencies in which such laboratories might be used. The recommendations are to include guidelines for modification of the field laboratories for use in emergency situations. The guidelines outline considerations that might enhance or detract from the use of mobile laboratories in such emergencies.

USE OF MOBILE WATER QUALITY LABORATORY ON A HAZARDOUS SPILL MISSION

In the event of spillage of hazardous polluting substances, the most immediate needs are for sampling capabilities and analytical methods of qualitative detection and quantitative determination of spilled material at toxic levels and at threshold concentrations for water quality impairment. In some instances, human sensory perception may be adequate, but for many materials, analytical methods will be required. The need for methods that can be employed rapidly in the field is particularly evident.

Several levels of detection capability are required in the event of a spill. Initially, there is a need for methods to discover that a spill has occurred. Subsequently, if the composition of spilled materials is not known, it must be determined rapidly. Finally, the concentration gradients in the environment must be followed until they are below the critical values. The procedures required to achieve these ends must be available from a single source and be easily accessible.

Both the water quality and air quality assessment capabilities of the mobile laboratories are deemed essential for most hazardous material spill missions. However, it is anticipated that the water quality laboratory would find itself on location for longer periods more frequently than the air quality laboratories because of the lack of countermeasures for air contamination and its more rapid correction through diffusion and meteorological events. Water pathway contamination, on the other hand, persists and continues to pollute through its course through the environment and must be monitored for extended periods.

Modification of the water-quality mobile laboratory for use on hazardous spill missions will be minor. The coliform and biochemical oxygen modules might be replaced with suitable detection equipment in case the spill is of unknown origin.

For the identification of soluble organic compounds, an infrared spectrophotometer and a spectra comparison process (automated through the use of a computerized retrieval technique) is necessary. When several unknown components are present, gas chromatographic techniques would also be required to facilitate infrared spectra detection. Most of the inorganics can be identified by the existing analytical capability in the water laboratory. Since expert chemists are part of the water-quality team, their knowledge can be employed to assist identification of hazardous materials through conventional qualitative chemical techniques.

USE OF EHL MOBILE LABORATORIES FOR NUCLEAR INCIDENT ASSESSMENT

In the case of an accidental release of radioactive material from a nuclear incident to the surrounding environment, a capability must be located near the incident site to evaluate this release in terms of eventual radiation exposure to the population either through direct contact or through biological pathways. Should the protection-action levels of exposure be exceeded, appropriate countermeasures as required would be initiated to minimize or reduce the exposure to an acceptable level. The same capability would monitor the effectiveness of the countermeasures being used.

Elements of the Air Force Environmental Health Laboratories' capability in health physics, water and air quality assessment could be called on to function in primary or support role. Their ability to be rapidly mobilized and transported to the site of the nuclear incident would provide a means for quick assessment of the magnitude and nature of the radioactive contamination. The specific functions of the mobile laboratories that would contribute to the overall activity would depend

on the total capability of the health physics component located at the site of the nuclear incident. However, the mobile laboratories are not designed to be placed within a region of radioactivity. They must remain at a safe distance and restrict their operation to monitoring as yet uncontaminated regions.

The sampling capabilities of both the air quality and water quality laboratories would be needed to assess the impact of a nuclear incident. The mobile laboratories would serve as the center for collection and concentration of radioactive air, water, and soil samples for radiochemical analysis. Biological samples would also have to be collected and prepared. The bioassay part of the water quality laboratory could fulfill such a need. With the addition of alpha, beta, and gamma counting instruments, the laboratories could do the complete assessment of the impact of the nuclear incident on the environment and recommend remedial action. However, the mobile laboratories cannot be used as a counting room as well as a sample preparation room because of the lack of shielding to stabilize or lower background radiation. To be effective this requires that the wall, floor, and ceiling by made out of several inches of concrete. Such modification, even if a comparably effective shielding of lower weight could be used, would be of a long term and expensive nature. In addition, the laboratory is not designed for ease of decontamination and could only be made so with considerable added expense and weight.

In order to operate within an area of or with products from a nuclear incident, a health physics support function would have to be assigned to the mobile laboratory to minimize the hazard to personnel. A decontamination facility for equipment and sampling gear, a contaminated refuse storage, special air filters, and nuclear radiation shielding of the laboratory and its water supply would have to be added to the laboratory. There is the probability that once the mobile laboratory had been used for such a mission, inadvertant contamination would rule out its future use. Except in dire emergencies, only the expendable part of a laboratory should be used on such a mission.

OTHER USES OF THE MOBILE LABORATORIES

The Department of Defense has under consideration an extensive demilitarization program to reduce stockpiles of chemical and biological warfare agents and explosive ordnance. The techniques being employed (or being considered) involve either incineration or chemical neutralization which produces product less toxic or hazardous than the original material. Such operations require extensive monitoring capability to assure that the effluent from these operations contains no toxic material and that the polluting constituents are held to within safe limits.

During incineration of such agents, a scrubber system on the exhaust capable of reducing NO_x, SO_2, HCl concentration to acceptable levels must be monitored continuously. In addition, the effluent must be checked for thoroughness of the incineration of the toxic materials or the other organic constituents. Such operations, of course, may have their own analytical services at the plant site. However, in the event of an operational emergency, the EHL mobile laboratories might be called in to provide rapid response backup to the existing facility or for monitoring environmental impact at remote locations.

Solid wastes from such operations, although presenting no hazard in the military sense, may contain inorganic salts that upon leaching could cause water pollution or toxification. These dried inorganic wastes must be disposed of by some means, such as sanitary landfills or storage underground in abandoned salt mines. Periodic monitoring of water pathways in such areas would be essential to assure continuous safe disposal. The water quality mobile laboratory could be used in such situations where a permanent analytical facility is not required.

The Air Force Environmental Health Mobile Laboratories could lend environmental control support in such operations for the Air Force, Army, or Navy demilitarization programs. Their function would remain in air and water quality assessment and no special equipment would be necessary. Specialized analytical procedures for toxic substances would be supplied by the organization in charge of the disposal operation.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

Requirements for mobile laboratory operations for water and air quality assessment set by field operations of the Air Force personnel and the design of operational mobile laboratories were analyzed. Design constraints for mobile laboratories fixed by the requirements that they be C-130 air transportable and land mobile were assessed. Various alternative structures such as self-propelled vehicles, trailers, and expandable shelters were evaluated. It was concluded that the most appropriate appropriate shell to house equipment and instruments is a modified warehouse van, fifth-wheel (semi-) trailer.

Present instrumentation used in analyses was judged adequate to provide unambiguous data for water-quality assessment. The addition of highly automated analytical systems is not recommended at this time because these require calibration against standard methods in the field.

The analytical system for stack sampling has only recently been standardized and probably will be modified in the near future. Ambient air sampling is in a state of flux in that some presently used supposedly standard techniques are being discredited and replacement techniques are still in development. Therefore, a laboratory should provide maximum flexibility for installation of instruments since specific instrument recommendations made at present may be outdated before the laboratory is built.

Since equipment requirements will be dictated by the exact nature and extent of the mission and not all elements of the field capability will be required on each mission, it was concluded that an interchangeable modular design based on the analytical function was the best arrangement to maintain mobile laboratory versatility. Such an arrangement also would provide the means for rapid response to a mission.

The mobile laboratory will have uses in emergency situations in addition to planned uses. Because of its quick-response capability, the laboratory can be quickly located at or near a site of an environmental emergency and provide monitoring and analytical capability for the team responding to the incident. The nature of the emergency, previous planning, and response time available will dictate whether the laboratory will be sent with or without modification.

It was judged overall that all critical analytical operations for water- and air-quality assessment can be incorporated into mobile laboratories of a size and weight to allow for air transportability and land mobility and provide adequate space and versatility to meet emergency functions. However, a complete water survey will require more than one unit, or additional space in a building at the test site. It is, therefore, recommended that the Air Force give serious consideration to the acquisition of such mobile laboratories.

APPENDIX I

SPECIFICATIONS

SPECIFICATIONS FOR MOBILE LABORATORY TRAILER

A. Mobile-Unit Shell: Warehouse type van. 27-in. drop, 40 ft long x 104 in. high when loaded with 10,000 lbs on rear axles. Trailer level with 44-in. high fifth wheel (light). Meet I.C.C. lights and safety requirements. Upper fifth-wheel plate, 3/8 in. thick. (See drawing)

B. Tires: 9.00-15, F load rating.

C. Suspension: Air-cushion.

D. Axle: Tandem.

E. Sand shoes: front and rear capable of supporting and leveling loaded trailer.

F. Doors: 4 as shown. 3-point hardware required. Locked doors must open without key from inside. 6-in. square window in two side doors (safety glass).

G. Windows: 5 required, safety glass. Curbside only, 1 ft high x 1-1/2 ft long. Bottom 5 ft above floor. Windows do not open. Seals water-proof.

H. Insulation: 2-in. polyurethane foan in walls, front, doors, roof and under floor, Vermin proof, nonsettling, nonhygroscopic, fungus, resistant, nonburning. Foam to be placed between aluminum skin and plywood walls. Floor insulation to be protected with 0.050-in. aluminum sheet.

I. Walls: 1/4-in. exterior grade, plywood inside. 0.50-in. aluminum outside. Posts with logistic supports. Paint inside walls one coat primer plus one coat expoxy hi-gloss enamel (colors to be selected later).

J. Floor: 4-in. I-beam cross members on 24-in. centers. 1-1/8 in. laminated hardwood floor. Cover with vinyl-asbestos tile, 1/16 in. thick (pattern to be selected).

K. Chain-ties: locate on all floor I-beams. 30-in. from each wall.

L. Tie-downs external: (24). Bolt tie-downs to inside of bottom rail on 20-in. centers. Tie-downs to Mil-Std-209 for 10,000-lb tie-down

M. Ports - on roadside, 2, 3-in. diameter. Seal holes. Provide plug to seal port when not in use.

N. Dolly: single axle. Dual wheels. Rigid fifth wheel. Height of fifth wheel when loaded with 7000 lbs is 42 in. Removable tongue. See Figure 15.

O. Ramp: 2 required. 25 in. high x 15 ft long and 3 ft wide as in Figure 16. 1/4-in. aluminum sheet. Mount on dolly. Capable of supporting tandem dual wheels with 6500 lbs per wheel load.

SPECIFICATIONS FOR UTILITIES IN MOBILE LABORATORY

A. Air conditioning and heating: air conditioner, minimum capacity 144,000 Btu/hr. Heater (electric) minimum capacity 25 KW. Air conditioners mounted in nose of trailer. Heater in front roadside corner of laboratory. Separate thermostats. If more than one air conditioner used, separate thermostats on each. Heating duct 12 in. high x 20 in. wide along roadside roof to door. Diffusers equally

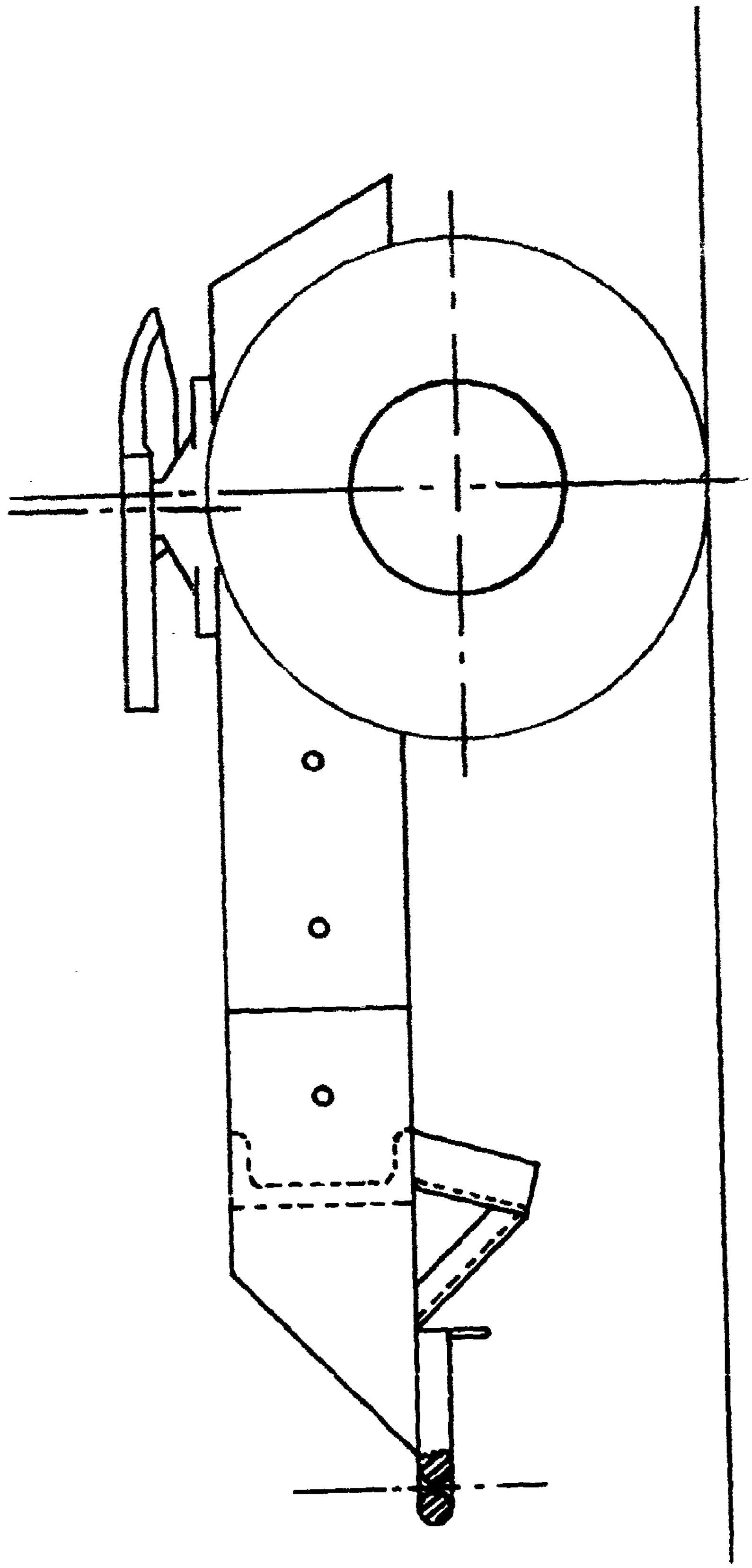

FIGURE 15. DOLLY

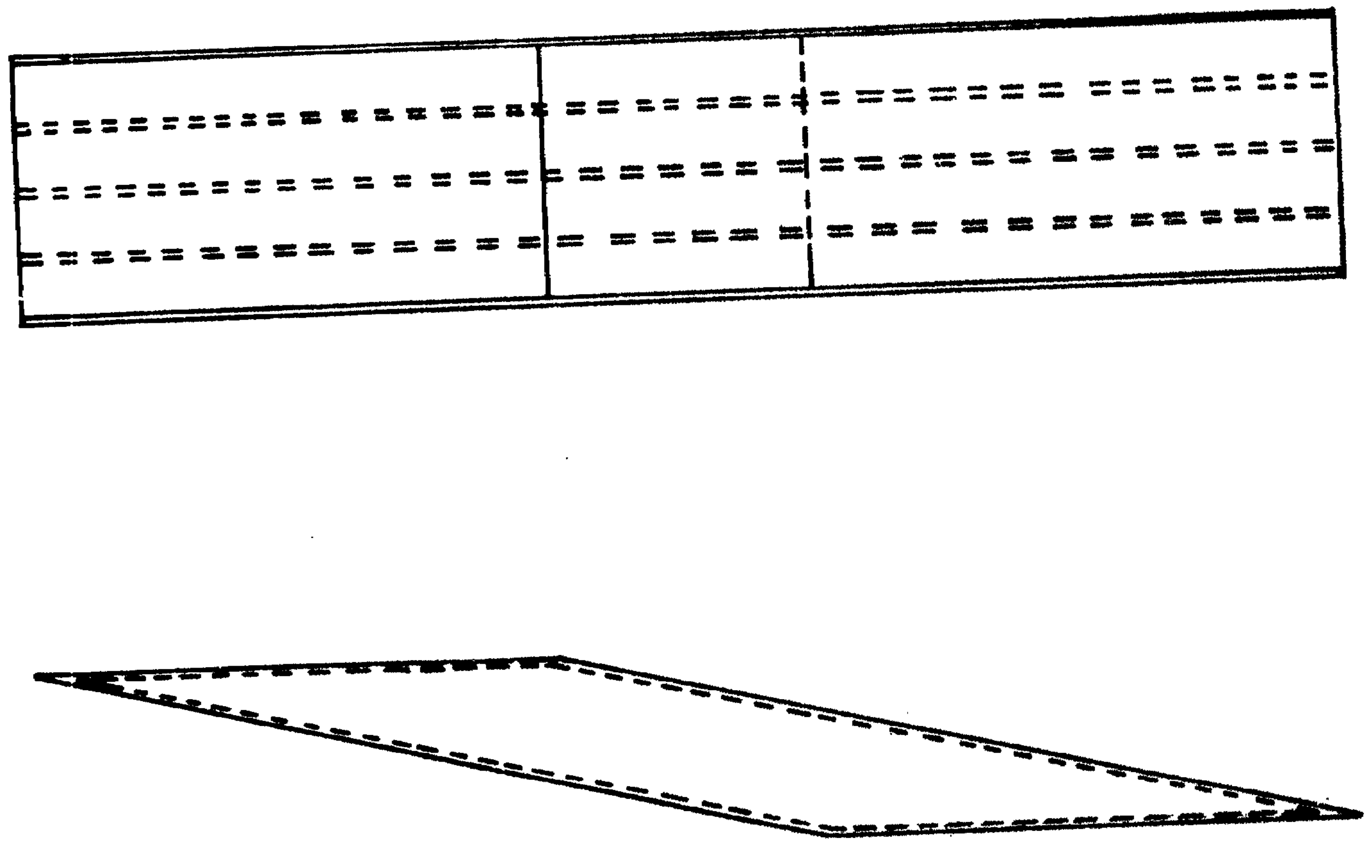

FIGURE 16. RAMP

spaced on side of duct, one on end of duct. Diffuser for 6 x 12-in. opening. Cooling duct common with heating duct. Second cooling vent in front wall, top curbside corner. Air returns under front bench. Makeup air supply from outside to enter return directly through barometric damper. Equipment capable of operating without changing wiring on 240-volt, single phase, 3-wire system or on two wires plus neutral of 208-120-volt, 3-phase system. One-half horsepower motor on fan (min.).

B. Electricity: electric inlet box is capable of input from 208-120-volt, 4-wire, 3-phase, 200-amp or 240-120 volt, 3-wire, single phase, 250-amp current.

Outlet circuits:

4 - 240-208-V, 40-amp, 3-wire circuits for air conditioners
4 - 240-208-volt, 30-amp, 3-wire circuits for utility outlets
2 - 120-volt, 20-amp, 2-wire circuits for lights
9 - 120-volt, 30-amp, 2-wire circuits for convenience outlets
1 - 240-208-V, 40-amp, 3-wire circuit for water heater
6 spares (minimum)

Wiring to meet NEC specifications for industrial wiring. Double convenience outlet, 15-amp rating, placed every 12 in. along side and front walls. Strips, track, Plugmold or other system of outlets acceptable. A new circuit every 6 ft of wall. Three-wire, 240-volt, 30-amp, utility outlets placed on side wall near each corner of laboratory. Convenience outlet in nose of trailer.

C. Lighting: Locked-in fluorescent, diffuser-type fixtures for two 40-watt bulbs lined end to end over work benches. 6 units each side, one over front bench. No fixtures over doors. Removable external light fixtures over door. Two fixtures for incandescent lights in room over nose of trailer, 3 switches in one box at middle door, one for each side and one for external lights. X P fixture in hood.

D. Steps: a 2-step ladder, 8-in. tread, 8-in. rise for each man door, a 6-step ladder for nose door. Store for transport inside of trailer. Provide firm attachment to trailer at top of steps.

E. Plumbing: all lines 1/2-in. I.D. copper tube. Solder connections.
Air Line: front, both walls 4 ft 3 in. above floor. Outlet every 6 ft plus sink outlets.
Drain line: roadside only. 3 ft 9 in. above floor. Valved inlet every 6 ft. Run line at ceiling to sink drain. Sink drains through wall. Sink drains connected by fire hose externally.
Water inlet: valved hose fitting. connect two together for outside water.
Water-heater drain: cut hole through floor. Plumb in and seal.
Valves: laboratory-type valves on walls. Kitchen-type valves at sink.
Water heater: cabinet model, dual 7000 watts, 50 gal, 24 x 25 x 36 in.

F. Ventilators: 12-in. square, about 500 cfm. Electrically reversible. Equipped with awning-type, spring-loaded door, hinged at top. Motors, 120 volts, 60 cycle operation.
    1 - in hood (explosion-proof wiring)
    2 - over each sink as close to ceiling as possible
    1 - under ventilating duct opposite front door of laboratory area on roadside

SPECIFICATIONS FOR BUILT-IN EQUIPMENT FOR MOBILE LABORATORIES

A. Sinks: 1 @ Stainless Steel 21-3/4 x 15-3/4 x 12 in. bowl, 36-in. cabinet; 1 @ Stainless Steel double bowl 14 x 17 x 10 in. bowl, 48-in. cabinet (plus or minus one in. on bowl dimensions).

B. Pegboards: 2 polyethylene, 35 x 1 x 24 in. Mount over sinks.

C. Laboratory benches: 3, plastic tops, locked drawers under those mounted on side of laboratory.

D. Water demineralizer, 4-holder pressure cartridge system with recirculating pump and water-quality meter.

E. Hood: custom-made, 72 x 24 x 36 in. To fit on laboratory bench.

F. Air compressor: single stage, 12-gal tank, 125 psi, 3/4-HP motor, 115-volt.

SPECIFICATIONS FOR AIR-QUALITY MODULES

A. Rack for mounting equipment per Figure 11.

B. Regrigerator, explosion-proof, under-bench type with freezer, 6.6 cu ft.

C. Storage, steel laboratory cabinets. 1 unit, 4 ft long, 3 units, 3 ft long.

SPECIFICATIONS FOR WATER-QUALITY MODULES

A. BOD: incubators and bottle storage on special mounts per Figure 2.

B. Phenol analysis: modified steel laboratory cabinets per Figure 3.

C. MBAS: modified steel cabinets and racks per Figure 4.

D. COD: modified steel cabinets per Figure 5.

E. TOD: modified cabinets per Figure 6.

F. Heavy metals: modified steel cabinets per Figure 7.

G. Coliform: incubator and sterilizer on special mount and cabinet per Figure 8.

H. Storage: steel laboratory cabinets per Figure 9.

I. Desk: 3-drawer steel units per Figure 10.

EXPLANATION OF SPECIFICATIONS FOR MOBILE-LABORATORY TRAILER

The specifications were deliberately written broad so that many companies could bid on the laboratory. The specifications define a mobile laboratory which fits into a C-130 aircraft and meets specifications for air-transportability. Deviations from specifications which do not affect these properties should not disqualify a supplier.

A. See text for choice of moving van. The fifth-wheel height of 44 in. was chosen as the normal level of trailer with the smaller wheels and tires specified under B. The fifth-wheel plate, 3/8 in. thick, is an obsolete industry standard retained by military specifications. It may be difficult to purchase.

B. The recommended tire is a 9.00-15 with a 12-ply (load range F) rating, which is smaller than the 10.00-20 tire which is most commonly used in the trucking industry. The smaller tire allows more headroom, at the expense of road clearance. Table 4 lists other tires considered. Any tire in the table with 3600-lb or greater capacity would be satisfactory. The axle load should not exceed 13,000 lbs, the C-130 limitation. This is equivalent to a tire load of 3250 lbs. The maximum load (gross) for the water-quality laboratory van based on the tire capacity of 9.00-15, load range F, tires is 28,000 lbs on the rear tandem axles. The total load, assuming a load of 14,000 lbs on the fifth wheel is about 44,000 lbs based on tire capacity. Another consideration is road

TABLE VII. LIST OF TIRES CONSIDERED

Size*	Ply	Load Rating**	Diameter, in.***	Load Capacity, lb****
7.50-15	10	E	33	2500
8.25-15	12	F	34.5	3100
9.00-15	12	F	36.4	3600
10.00-15	12	F	37.8	3800
7.50-20	10	E	38.1	3100
8.25-20	12	F	39.7	3700
9.00-20	12	F	41.5	4300
10.00-20	12	F	43.0	4500

* 16,17,18,22,22.5, and 24.5-in. rims and tires available.

** The tire dimensions are independent of load range. A change in rating from F to E reduces capacity by about 10 percent. An E-rated tire runs softer than an F-rated tire. G-rated tires are frequently used for very heavy loads at low speeds.

*** Diameter varies somewhat with brands. Diameter shown is maximum allowable. Typical diameters are 1-1/2 in. smaller. The loaded radius is about one inch less than the unloaded radius of the tire.

**** Capacity varies with speed and inflation. The capacity shown is the middle load used in the SAE endurance test and is slightly greater (perhaps 10 percent) than the normal working load in highway use. Lighter loads give longer tire life.

clearance. The 15-in. clearance with these tires is close to the practical minimum required for over the road transport. A minimum of 14 in. is required by military specification.

C. Air-cushion springs are specified to provide a softer ride than the standard leaf spring. This is especially important in transporting instruments which lose calibration under rough treatment. The U. S. Army mobile vans used leaf springs and reported instruments lost calibration in shipment.

D. The laboratory uses tandem axles because of the greater load and because tandem axles give a softer ride than a single axle. The trailer could use a single axle but the load would have to be carefully distributed to prevent overloading. Therefore, to give greater freedom in loading and to permit increase in mission size, tandem axles are specified.

E. In addition to the normal sand shoes behind the fifth wheel, a pair of sand shoes are needed behind the rear wheels. These shoes shall be capable of leveling the trailer and lifting the wheels off the ground. This is necessary to prevent movement of the laboratory while at the test site.

F. Four doors are required in the water-quality laboratory. Doors shall open from the inside without a key even if they are locked from the outside to permit emergency exit at any time. A 36 in. wide, full-height access door shall be provided at the curbside for entry into the utility room. 36- and 30-in. wide, full height doors shall be provided as shown for man entry into the van. The rear 30-in. door could be omitted and the cargo doors used. However, this is considered less convenient. The double cargo doors in the back will be used for loading and unloading. They will not be needed for man access.

G. Windows are primarily for aesthetic reasons. On the doors they are a safety feature.

H. This specification is the standard insulating procedure for refrigerated trailers.

I. Standard trailer construction. Epoxy paint will withstand repeated washing.

J. Standard floor except for vinyl asbestos. Vinyl asbestos will protect the wood from water and chemicals and can be replaced inexpensively if a chemical spill causes serious damage.

K. The chain-ties are used to tie equipment into the aisle during shipment. They will be level with the floor when not in use.

L. Twelve external tie downs on each side will restrain at about 240,000 lbs or the anticipated load at 9g. With the built-in safety factor this is more than adequate to restrain the trailer

M. Ports required for ambient air sampling.

N. Because of headroom requirements, a tractor cannot be used to load the laboratory into the C-130 aircraft. Therefore, a dolly with a rigid fifth wheel mounted at a loaded height of 42 in. is specified for loading th e laboratory on a C-130. The tires will be the same as on the trailers. The tire capacity of the dolly will be over the 13,000-lb capacity of the aircraft floor. The design of the dolly is straightforward and alternatives were not considered. The same tire size as the trailer is used to simplify inventory and to provide a spare tire in transit.

O. A ramp is needed to load the 40-ft trailer on the aircraft because the clearance between it and the aircraft floor is inadequate using

existing ramps. The ramp can be stored on the dolly during land transport operations. The ramp can be loaded into the aircraft under the trailer during air transport. The details of the ramp are shown in Figure 16.

EXPLANATION OF UTILITY SPECIFICATION

A. The very large air conditioner is needed for cooling because of (1) the hood, and (2) the heat loads from equipment. Table VI presents an estimate of peak heating and cooling needs in the water-quality laboratory. The air conditioner is of smaller capacity than estimated because the hood will not be operating all of the time and some of the electric-heat load is adsorbed in water-cooled condensers. The 12- x 20-in. duct is undersized for the heating and cooling load because of space limitations. The resulting high velocity of air in the duct may cause some noise.

B. The available inlet electrical power will vary with location. The Air Force standard is a 208-120 volt, 3-phase, 4-wire system and should be available on most Air Force Bases. Nonmilitary distribution varies but 240-120-volt, single-phase, 3-wire systems are most common. Therefore, the laboratory should be capable of using either type of electrical power. Conversion can be made at the inlet box by the base electrician who connects the laboratory to the power source. Operation of 120-volt apparatus will be unaffected by the change. Equipment for 240-volt operation must be specified for 240-208 volts or it may be damaged by 208-volt operation. The inlet current rating of 200-amp, 3-phase or 250-amp, single-phase is needed because of the large laboratory and air conditioning load. In mild weather where heating and air-conditioning are unnecessary, 60-amp, 3-phase, or 100-amp, single phase power source would be adequate.

Electric outlets and plugs are normally used only for current ratings up to 50 amp. Larger outlets and plugs are special order items and would require more work for installation than solidly wiring the laboratory into its power supply. Wires of 300MCM are required to carry 250 amp. Presumably the base visited will supply the wire to connect the trailer to the electric power supply. Connecting and disconnecting heavy wires requires an electrician.

Utility outlets for 240-volt, 3-wire, 30-amp current are specified because some equipment may require this power. Much equipment drawing more than 1500 watts requires 240 volts. Nine convenience circuits are specified. These will supply up to 27 KW of power. The outlets are specified as 15 amp because of the large number of furnaces with a heavy power drain. Outlets with greater capacity are of a different size.

C. Fluorescent lighting gives good illumination without shadows. Two bulbs over each bench will illuminate sufficiently for close work. Since the bulbs are at about eye-level, diffusers are needed to prevent workers from looking directly into bulbs. No lights are provided over the aisle because of headroom limitations. The lights are in the room over the nose for maintenance operations.

D. The steps are needed for entry since the floor will be about 23 to 24 in. above ground.

E. Air and cold water are installed on all walls for convenience. Hot water is not needed except at the sinks. Curbside drains connect to each sink.

F. One ventilator is designed to exhaust the hood. The other ventilators are designed for general ventilation. However, they can be modified to work as fans for portable hoods.

EXPLANATION OF SPECIFICATIONS FOR BUILT-IN EQUIPMENT

A. Stainless steel sinks were specified at the recommendation of the personnel in the army mobile laboratory. The EPA used Ducon plastic sinks with satisfactory results. Either would be acceptable.

B. Pegboards are handy to dry glassware.

C. Wooden benches with chemical resistant plastic tops are specified because they weigh less than the alternate stoneware benches. The benches are placed where cabinets cannot be used because the wheel wells or the front step is under the bench. No drawers are provided in the front bench because the space is needed for a cold air return for the heating system.

D. See explanation in text.

E. A custom-made hood is needed as standard hood will not fit because of the limited headroom of the trailer.

F. This size of air compressor should be adequate.

EXPLANATION OF SPECIFICATIONS FOR MODULES

A rack made of slotted angle was chosen because the spacing can easily be adjusted for new or different equipment.

The refrigerator is explosion-proof because volatile organic may be stored in it.

Laboratory cabinets were chosen because of their versatility in storing equipment, because they are readily available, and because laboratory workers are familiar with them.

The equipment modules were described in the text and generally consist of equipment for a particular analysis mounted on laboratory cabinets. Detail drawings were not needed because equipment of the type specified was made by many manufacturers and minor differences in details are not important.

APPENDIX II

COST ESTIMATES

The costs were estimated by obtaining a unit cost estimate of the trailer and dolly from a commercial trailer manufacturer. The laboratory equipment costs were estimated from catalogs. Other costs were estimated by experience and judgment. Generally, preliminary estimates of this type are low because of omitted costs.

Table VIII presents the costs for the laboratory. No instrumentation or laboratory apparatus cost is included.

TABLE VIII. ESTIMATED COST FOR LABORATORIES

Unit	Subunit	Estimated Cost, Dollars	
Trailer			
	Shell		15,000
	Dolly		3,000
	Ramp		2,000
	Vinyl Floor	Material	60
		Installation	100
	Air Conditioning	Material	4,000
		Installation	1,000
	Heating	Material	300
		Installation	50
	Ductwork	Material	100
		Installation	300
	Electricity	Material	1,500
		Installation	1,000
	Lighting	Material	800
		Installation	300
	Steps	Material	100
		Installation	50
	Plumbing	Material	200
		Installation	200
	Ventilators	Material	200
		Installation	100
TOTAL			30,360
Built-in Equipment			
	Deionized Water Supply	Material	1,400
		Installation	300
	Air Compressor	Material	150
		Installation	50
	Water Heater	Material	100
		Installation	50
	Benches	Material	1,150
		Installation	100
	Sinks	Material	550

TABLE VIII. (Continued)

Unit	Subunit	Estimated Cost, Dollars	
	Sinks	Installation	100
		Material	50
	Hood	Installation	200
TOTAL			4,200
Modules	BOD		120
	Phenol		940
	MBAS		1,450
	COD		740
	TOD		430
	Heavy Metals		740
	Coliform		260
	Other Installation		300
	Air Refrigerator	Material	700
	Rack	Material	400
	Air Storage	Material	2,000
	Desks	Material	1,000
	Bioassay Storage	Material	2,000
TOTAL			11,080
GRAND TOTAL			45.640

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT (Distribution Limitation Statement B) The Air Force requirements for a mobile field laboratory were determined by visits to McClellan and Kelly Environmental Health Laboratories and by observations of a Kelly field team surveying the waste-water problems at McGuire Air Force Base. The major requirements of mobile laboratories are: 1) they should be a container for unified damage-free shipment of the laboratory equipment, 2) they should provide working space for the field team and a place to use analytical equipment, 3) they should reduce the set-up, tear-down, packing, and unpacking time and manpower requirements, 4) they should be transportable on the public highway and by C-130 aircraft, 5) they should provide laboratory utilities. The technology for mobile laboratories was determined by visits to the EPA and US Army mobile laboratories and by telephone contact with many other mobil- laboratory operators. Existing laboratories would not meet all of the Air Force requirements, primarily because none fitted into a C-130 aircraft and partly because each laboratory was designed for the specific missions which were different from Air Force missions. After evaluating several alternate designs, mobile laboratories for air- and water-quality analyses were designed into a modified, semi-trailer. Other field analytical groups in the Air Force could use mobile laboratories based on these designs. The utility functions--heating, cooling, hot and cold water supplies, electricity, and compressed air--were designed permanently into the semi-trailer. The analytical functions were designed into modules which could be placed in, and removed from, the laboratory as required by the specific mission. The overall cost of a mobile laboratory without analytical modules was estimated at $34,560 and the cabinetry associated with the analytical modules at up to $11,080, depending upon the specific modules chosen.

14 KEY WORDS	LINK A		LINK B		LINK C	
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Environics						
Air pollution						
Civil engineering						
Field laboratory						
Chemical laboratory						
Industrial hygiene						
Water pollution toxicology						